





PROCEEDINGS

XVIII INTERNATIONAL CONGRESS OF ENTOMOLOGY

**Vancouver, B.C., Canada
July 3 to 9, 1988**



ABSTRACTS AND AUTHOR INDEX

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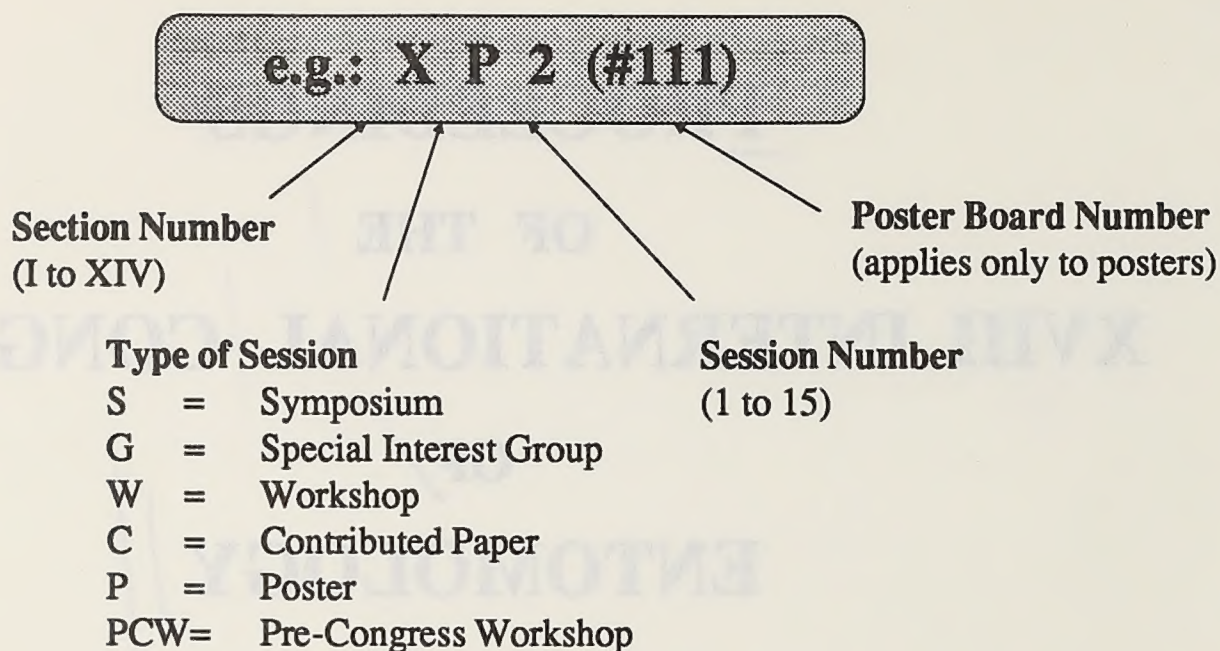
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ABSTRACTS
AND
AUTHOR INDEX

KEY TO SESSION IDENTIFICATION



ARRANGEMENT OF ABSTRACTS

The abstracts are arranged on pages in order of presentation within each session. The sequence of abstracts (a,b,c,d,e,f,...) for each page is shown to the right. The "*page position letter*" accompanies the page number in the index. Poster papers, however, are numbered according to their poster board location within each session.

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EDITORIAL NOTE

The majority of the abstracts in this book have not been edited by the Organizing Committee and are presented as received. A few abstracts were retyped because they were submitted in a form not suitable for publication, or in an incorrect format.

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Opening & Closing Lectures

Opening Lecture

JUVENILE HORMONE: METAMORPHIC AND GONADOTROPHIC REGULATOR *or YOU CAN'T GET TO THERE FROM HERE!*

Stephen S. Tobe, Department of Zoology, University of Toronto, Toronto, Ontario, Canada M5S 1A1

Is juvenile hormone (JH) a sexist hormone? Does it regulate metamorphosis? Although evidence indicates that JH is a central player in both female reproduction and metamorphosis, it remains difficult to reconcile the role of the hormone as a metamorphic regulator *vs.* its role as a gonadotrophic stimulant.

"You can't just turn back and get there from here!" Have we 'juvenile endocrinologists' adequately set the stage for the impending explosion of molecular biology into our field? Perhaps. We have certainly defined any number of intriguing phenomena and questions. And recombinant DNA technology may provide 'definitive' data on the regulation of gene expression by JH during development and reproduction. The task to interpret these data and to place them in the context of the physiology of the insect will fall to us.

The study of the pathway and regulation of JH biosynthesis will remain an important area, notwithstanding the trend to endocrinological 'reductionism'. Homologies with other arthropod endocrine systems may provide clues on the mechanisms of regulation of JH production and on the evolution of the biosynthetic pathway.

Although the route may be contorted, *"you can get to there from here"*.

Closing Lecture

SEX PHEROMONES: WHAT DO WE REALLY KNOW ABOUT THEM?

W. L. Roelofs, Department of Entomology, Cornell University, Geneva, New York 14456.

Research programs on insect sex pheromones increased exponentially throughout the 60's as interest and funding was targeted at developing new methods of insect control. The sex pheromones of hundreds of species subsequently were identified for use in IPM programs. Some of the glitter of pheromone research was lost, however, when efforts to utilize pheromones for insect control were unsuccessful in some cases, hampered by politics and/or economics in other cases, and unrealistic in others. Although pheromones have found their way to the commercial market in a number of cases and the potential exists for their use in many more, the great enthusiasm for this research as seen in the 60's has waned.

Nevertheless, this chemical communication system has proved to be a gold mine for research in biochemistry, behavior, neurophysiology, morphology, electrophysiology, genetics, ecology, evolution, biotechnology, etc. etc. This tightly controlled communication system, which is so important in maintaining species specificity, involves an emitter and a receiver and all the ramifications of their functioning, coordination, and transmission of signal. It is a system that still has great opportunities open for basic research for those that approach it with interdisciplinary insight and creativity.

Molecular Biology, Genetic Engineering And Its Relevance To Pure And Applied Entomology

THE TOOLS OF RECOMBINANT DNA TECHNOLOGY, GENE TRANSFER SYSTEMS AND THEIR APPLICATION TO INSECT DEVELOPMENT
Robert B. Saint, CSIRO Division of Entomology, GPO Box 1700, Canberra City, ACT 2601.

Recombinant DNA techniques have revolutionized the study of many aspects of biology. Application of these techniques is already contributing to problems of both basic and applied significance in entomology. Furthermore, greater understanding of the biochemistry, physiology and behaviour of insects is certain to create novel approaches to many problems in the longer term. The purpose of this presentation is to review the technology involved in DNA manipulation and to discuss general areas of application to entomology. Included in the discussion will be the nature of gene and chromosome structure and function, development, physiology, behaviour and the characterization of insect pathogens. I will also discuss the application of these techniques to the genetic modification of economically important insects, both pests and beneficials, and to insect pathogens. Finally I will discuss the converse of the above relationship between molecular biology and entomology - the contribution of insect model systems to general biological questions - using the problem of animal development as an example.

MOLECULAR BIOLOGY AND THE STUDY OF INSECT POPULATION BIOLOGY, EVOLUTION AND SYSTEMATICS. R. G. Harrison, Section of Ecology and Systematics, Cornell University, Ithaca, NY.

Indirect and direct methods for assessing DNA sequence divergence have become the quintessential tools for obtaining data on genetic variation and genetic relatedness. Recombinant DNA technology and the markers it provides are playing an increasingly important role in insect systematics and evolutionary biology. Markers and methods can be found that are appropriate for resolving problems at all levels in the evolutionary hierarchy (from distinguishing lineages within populations to phylogenetic analysis of higher taxa). The level of resolution depends on choice of method (sequencing, restriction site mapping, DNA-DNA hybridization) and choice of marker (mitochondrial DNA, rRNA genes, specific single-copy nuclear genes). I examine the strengths and weaknesses of these approaches and of the various classes of DNA sequences from which information can be obtained. Through a series of insect examples, I evaluate the current status and future potential of DNA sequence variation as a genetic marker for distinguishing insect species or races and for identifying the source of introductions. I then consider the uses of molecular genetic tools in the study of insect population structure, gene flow, hybridization and phylogeny.

INSECT NEUROPEPTIDES: POSSIBLE LEADS TO NEW CONTROL METHODS
M. O'Shea, Laboratoire de Neurobiologie, Université de Genève, 20 rue Ecole de Médecine, CH-1211 Genève 4, Switzerland.

Neuropeptides represent the largest and most diverse class of effector compounds in insects. Perhaps a hundred different peptides are involved in regulating various aspects of insect behavior, development and metabolism. In this paper I will review the field of insect neuropeptide biology and show how basic knowledge may be used in the development of novel control compounds.

I will show how molecular biological methods can be applied to the discovery of new bioactive peptides. Knowledge of peptide structure alone however is insufficient. In order to exploit neuropeptide systems as targets for new control methods we need to understand i) how peptides are synthesised, ii) what regulates biosynthesis, iii) what controls peptide release, iv) how the peptides interact with receptors to produce the physiological response and v) how bioactive peptides are finally inactivated and metabolized. Within each of the above categories there may be opportunities to develop interfering compounds with insecticidal action. In order to pursue these opportunities it will be necessary to apply both molecular and biochemical methods in the study of insect peptidergic systems.

BIOTECHNOLOGY IN INSECT SYSTEMS, GENETIC ENGINEERING OF INSECT PATHOGENS. Dr. Max D. Summers, Texas A&M University, Department of Entomology, College Station, Texas 77843.

- A. Genetic Engineering of Baculoviruses
 1. Baculovirus-directed foreign gene expression.
 - a. Characteristics of the BEV and its utilization.
 - b. Cost effective synthesis of therapeutics, vaccines and diagnostics in insect cells and insects.
 - c. The "authenticity" of recombinant products produced in insect cells.
 2. Studies of the molecular biology of insect cells and systems: cloning, expression and study of genes of agricultural importance using the BEV.
 3. Transposable elements in baculovirus mutants.
 - a. Characteristics of the mutants.
 - b. Potential for development as transfer vectors into lepidopteran cells and insects.
- B. Bacterial Pathogens: Genetic Engineering of Bt and Bti for crop protection and insect pest control (a very general overview).

MOLECULAR GENETICS OF NEURONAL RECOGNITION DURING *DROSOPHILA* DEVELOPMENT. Corey S. Goodman, Tom Elkins, Allan Harrelson, Roger Jacobs, Linda McAllister, Nipam Patel, Peter Snow, Kai Zinn, Dept. of Biochemistry, Univ. of California, Berkeley, CA 94720

To identify candidates for neuronal recognition molecules, we generated monoclonal antibodies (MAbs) which recognize surface antigens expressed on subsets of axon fascicles in the grasshopper and *Drosophila* embryos. These MAbs were used to characterize and purify three different surface glycoproteins, called fasciclin I and II (in grasshopper) and fasciclin III in *Drosophila*, which are transiently expressed on different overlapping subsets of axon fascicles during embryonic development. The genes encoding all three fasciclins were cloned using a combination of oligonucleotides (based on microsequence data) and cDNA expression cloning (using serum antibodies). We then used the grasshopper fasciclin I cDNA to clone the fasciclin I homologue in *Drosophila*.

We have identified viable mutants of both the fasciclin I and fasciclin III genes. Fasciclin III mutants have abnormalities in cell migrations, pathway formation, and axon fasciculation. Double mutant combinations of these genes lead to much more profound mutant phenotypes, further supporting the notion that neuronal recognition is both combinatorial and to some extent redundant in terms of the number of different guidance cues used by neuronal growth cones to find their targets.

NEUROCHEMICAL AND MOLECULAR ASPECTS OF SYNAPSES AND SYNAPTIC TRANSMISSION IN INSECTS. H. Breer, Institute of Zoophysiology, University Stuttgart-Hohenheim, 7000 Stuttgart 70, West Germany.

Isolated nerve terminals from the highly cholinergic nervous system of insects have been used to study the energetics and regulation of the high affinity transport system for choline which is supposed to be the regulatory step in the synthesis of acetylcholine. Specific ligands as well as monoclonal antibodies have been used in attempts to identify the molecular elements of the carrier system. Principles for modulating the evoked, Ca^{2+} -dependent release process for acetylcholine have been explored in microfusion experiments. Subtypes of muscarinic and nicotinic receptors for acetylcholine have been detected in the nervous system of insects. A nicotinic receptor has been isolated from locust ganglia and reconstituted in planar lipid bilayer, where it showed all properties of an agonist activated cation channel. Immunological approaches revealed a selective localization in the ganglionic neuropil and some molecular similarities to the peripheral vertebrate receptor. RNA-preparations from locust nervous tissue were probed for receptor-specific mRNA using reticulocytes and *Xenopus* oocytes as expression systems.

NEUROBIOLOGY OF INSECT LOCOMOTION. K.G. Pearson, Department of Physiology, University of Alberta, Edmonton, Canada.

Over the past four years our knowledge of the neural mechanisms controlling insect locomotion has increased considerably. Three notable technical achievements have been 1) the development of preparations for recording intracellularly from identified neurons in flying and walking animals, 2) the routine use of double microelectrode recording for determining the connections between identified neurons, and 3) the development of methods for selectively stimulating specific groups of receptors in behaving animals. These advances have yielded important information on the central neuronal circuits for the generation of rhythmic motor activity and for the integration of proprioceptive and exteroceptive information, the mechanisms by which proprioceptive input contributes to pattern generation, and the mechanisms by which exteroceptive information modulates locomotory activity. Recent data in each of these areas will be reviewed in this presentation.

METAMORPHOSIS OF THE CNS: IMPLICATIONS FOR UNDERSTANDING THE DEVELOPMENT AND DIVERSITY OF THE INSECT NERVOUS SYSTEM. J.W. Truman, Department of Zoology, University of Washington, Seattle WA 98195, U.S.A.

During the past 10 years a number of techniques have allowed us to follow changes in the segmental ganglia of the moth *Manduca sexta* during metamorphosis. Embryogenesis results in a reduced, larval CNS that has all of the major tracts and commissures of the adult. The larva has a full complement of motoneurons but many other neuronal populations, especially those related to sensory processing, are grossly underrepresented. The larval CNS serves as the scaffolding for the construction of the adult CNS and many larval cells are remodeled during metamorphosis for their new adult functions. The neurons that make up the remainder of the adult CNS arise during larval life. The embryonic neuroblasts, which had become dormant late in embryogenesis, reactivate and generate the remainder of their respective lineages during larval growth. The neurons that are born at this time appear to play no role in larval behavior but are sequestered as partially-differentiated, post-mitotic cells which mature into functional neurons at metamorphosis. These new cells are primarily local interneurons that are likely involved in processing adult-specific sensory input. These observations will be discussed in terms of how this holometabolous pattern is modified in various groups and how it may have arisen from the hemimetabolous plan.

VISUAL INFORMATION PROCESSING CONTROLLED BY A CIRCADIAN CLOCK. Guenther Fleissner, Zoologisches Institut, Universität Frankfurt, Siesmayerstr.70, D-6000 Frankfurt/Main, FRG

Visual systems are well known for their complexity of information processing. This contribution focusses on a less frequently treated component of this complexity: efferent control of afferent visual information flow.

Through efferent control, a circadian clock can set boundaries to the working range of the visual system at all stages from retina to brain. Thus, even in constant light conditions, visual information processing can be fundamentally different in time, oscillating between subjective day and night state. The neuroanatomical basis of this phenomenon is still poorly understood.

This paper proposes a model for circadian control of vision and describes anatomical and functional characteristics of efferent fiber systems. Aminergic components (5HT and octopamine) and possibly peptidergic elements (PDH, pigment dispersing hormone) are involved. The data are based on results from histological, electrophysiological and behavioral experiments on the visual system of beetles, complemented by data from chelicerates.

MECHANICS AND ENERGETICS OF INSECT FLIGHT. C.P. Ellington, Department of Zoology, University of Cambridge, Downing Street, Cambridge CB2 3EJ, England.

Studies on the kinematics, mechanics, aerodynamics and energetics of insects in free flight have greatly advanced our knowledge during the past decade. These results contradict some long-standing and widely held beliefs, and they form the foundations of a revised understanding of the flight system. Particular emphasis will be given to the aerodynamics and energetics of flight.

SENSORY CONTROL OF INSECT FLIGHT. K.G. Goetz, Max-Planck-Institut für biologische Kybernetik, Spemannstrasse 38, D-7400 Tübingen, FRG.

Wingbeat in insects is modified by sensory input signaling (1) stretch and contraction within the flight system, (2) airspeed and temperature on the body surface, (3) displacements of the body relative to the visual background, the inertial system and the directions of gravity and magnetism, (4) position and attraction of visual, acoustical and olfactory targets.

New facts about visual flight control in the fruitfly *Drosophila* underline the significance of the context of sensory input. (1) At least three pairs of flight control muscles respond to displacements of the retinal images of figure and ground. Each pair contributes to fixation and tracking of a figure, and to stabilization of course and altitude with respect to the ground. Two pairs support a rigid strategy of 'instructional' fixation. The third pair engages in a flexible strategy of 'operant' fixation suitable to cope with artificially inverted displacements. Relapse to 'instructional' fixation is found in the corresponding muscles of the mutant 'small optic lobes'. (2) Relative movement between figure and ground indicates proximity of the figure, and seems to serve for longrange depth perception during free flight. Tethered flies prefer the nearest figure which might be attractive as a landing site. The attraction subsides gradually whenever the figure is moving in conjunction with the ground. Fixation of a figure requires about 5 course-control manoeuvres/s, and can be maintained for 24 h of tethered flight in a simulator.

THE ORIGIN OF THE INSECT WING. J. Kukalova-Peck, Department of Earth Sciences, Carleton University, Ottawa, Ontario, Canada K1S 5B6.

The proto-wing homologue (1) is at least as old as the insect lineage, (2) evolved from an evagination between leg segments (probably 1st and 2nd), (3) was always articulated and mobile, (4) was serial. Evidence is consistent as follows. Paleontology: primitive nymphs have fully articulated winglets and some could very probably fly. Some fossils have both serial winglets and leglets on abdomen. Morphology: wings and abdominal winglets (gills) of Ephemera are surrounded by identical leg muscles. Genetics: embryonic wing polyclones separate from leg polyclones; one homeotic mutation switched wing rudiments to the abdomen. Ontogeny: wing anlagen occur just beyond thoracic spiracles, evaginate and shift gradually upwards to secondarily fuse with tergum; the wing pouch in crane fly larvae is connected to the leg pouch. Neurophysiology: neural branching for wings also occurs in abdomen and sometimes generates flight impulses. Tissue transplants: moth wing discs develop into wing blade and complete wing articulation. All this evidence points to wing origin from the arthropod respiratory-locomotory leg exites. Legs of Paleozoic insects bear up to 5 exites; flattened epicoxal exites are probably the wing homologues.

ARE INSECT MUSCLES REMARKABLE AS MUSCLES? Robert K. Josephson, School of Biological Sciences, University of California, Irvine, California 92717, USA.

The highest known contraction frequencies and metabolic rates of any muscles are found in insect flight muscles. Despite their sometimes extraordinary performance, in many ways insect flight muscles are similar to muscles elsewhere. The ultrastructural organization of flight muscles is qualitatively similar to that of striated muscles throughout the animal kingdom. Muscle contraction kinetics have been determined for only a few insect flight muscles, but it appears that maximum shortening velocity, maximum tension, and the relationship between muscle length and maximum tension are not different from fast vertebrate muscles. Estimates of mechanical power output from insect flight muscles are higher than other muscles examined, but the gap between power output in insect flight muscles and some other muscles is not large. Those insect flight muscles which are asynchronous muscles do differ from other muscles in that contraction frequency is determined mechanically and not by neural input patterns, but the features which allow asynchronous operation - shortening inactivation and stretch activation - are found in and contribute to the performance of many other muscles. Insect flight muscles are part of a broad and continuous spectrum of muscle diversity in animals.

CENTRAL NERVOUS CONTROL OF INSECT FLIGHT: A COMPARATIVE APPROACH. R.M. Robertson, Department of Biology, McGill University, 1205 Avenue Docteur Penfield, Montreal, P.Q. Canada H3A 1B1.

The nervous control of neurogenic flight in insects can be divided into two components: peripheral and central. The central component results from the operation of a circuit of interneurons and motoneurons in the thoracic nervous system. For many species of insect this circuit is capable of producing a flight motor pattern in isolation from peripheral feedback and can be investigated in dissected preparations using conventional intracellular recording and staining techniques. Comparison of the properties and interactions of interneurons of different insects should reveal features of neural organization that are adapted to particular flight mechanisms and behaviors.

Most information on the properties and organization of flight interneurons has accumulated for the locust, *Locusta migratoria*. Recently I have described the structure and some of the properties of flight neurons in the cricket, *Teleogryllus oceanicus*. Similarities in interneuronal organization in the flight systems of locusts and crickets can be observed. However, the large differences prevent meaningful comparison and suggest that no single flight system will ever provide an adequate model for the generation and control of neurogenic flight.

PREDATOR EVASION AND THE ORIGIN OF FLIGHT IN INSECTS. John S. Edwards. Department of Zoology NJ-15, University of Washington, Seattle, WA 98195.

Recent hypotheses have emphasised the evolution of a capacity for dispersal in patchy habitats as the adaptive context for the acquisition of flight by insects. An alternative hypothesis stems from earlier proposals by Bristowe and by Hinton that predator evasion was an initial factor. My argument is based on neuroethological evidence that the abdominal giant interneuron system and associated abdominal cerci common to polyneopteran orders and which is represented by homologous neurons and sensory appendages in modern apterygote insect orders, arose as a predator evasion system in stem prepterygote insects. Output from the giant interneurons activates thoracic locomotor centers. The acquisition of jumping locomotion in response to giant fiber input provided the symmetrical coordination of what became the bifunctional flying musculature. It is proposed that in prototype jumping behavior lateral coxal appendages had a transient effect in prolonging or stabilizing ballistic trajectory. Subsequent refinement of the flying leap led to active flight. Exploitation of patchy environments through dispersal flight then became adaptively significant. Supported by NIH grant NB 07778

a – Plenary Lecture

THE VALUE OF SPERM AND EGG STRUCTURE IN INSECT SYSTEMATICS. Baccio M. Baccetti, Department of Evolutionary Biology, University of Siena, via Mattioli 4, 53100 Siena, Italy.

Insect spermatozoa have evolved in an impressive array of different models, in several evolutionary lines clearly corresponding to the different Orders or groups of Orders, and radiating from a primitive model. The many adaptations in the various families and genera are closely related to the perfection of the copulatory organ, the sperm storage, the presence of micropyles in the egg, and consequently are recurrent in the different Orders. Thus, a similar series of structures seem to have been realized, step by step, independently in the evolution of the Protura, Isoptera, Thysanoptera, Rhynchota, Coleoptera and Diptera. Generally, we see an evolution towards increasing length and motility, achieved from a hypertelic model of sperm which progressively reduces its motile ability, realizes unusual axonemal patterns and culminates in aflagellarity. A parallel evolution is observed in the various phases of simplification and total abolition of the acrosomal complex in the species having eggs with micropyles. In this general picture, it is clear that genera and species can differ in various characters that can be useful in taxonomy and construction of phylogenies. Recent phylogenetic uses of this information have been in the systematics of Phasmatodea, Orthoptera, Diptera and Coleoptera (Chrysomelidae and Curculionidae).

The egg structure has evolved in parallel in various insect groups, and has resulted in the acquisition of important new structures in the chorion and quality of the vitelline proteins, both closely related to the diversities in oviposition. Changes have also occurred in the respiratory system, in water relations, presence of oothecae or shells, the length of embryogenesis, and have eventually resulted in viviparity. While the vitelline protein complex has not yet been widely used for phylogenetic or taxonomic purposes, the beautiful recurrent structure of the chorion in the many Orders has received attention mainly from scanning electron microscopists. However, the interesting evolutionary pathways are fairly evident. Systematics has benefitted from the acquisition of these new data in the study of the Phasmatodea, Orthoptera, Ephemeroptera, Rhynchota and Diptera.

b – Plenary Lecture

EVOLUTION AS REVEALED BY THE WING OF CRICKETS.

Sinzo Masaki, Laboratory of Entomology, Faculty of Agriculture, Hirosaki University, Hirosaki 036, Japan.

The wing of crickets is a highly variable structure, posing challenging problems for the study of evolution. Different species show different wing forms ranging from macropterous to apterous states with a graded series of intermediates. This interspecific variation can be related to species-specific life styles and suggests various evolutionary factors involved. Many species are dimorphic and switch from one to the other wing form under the control of interacting genetic and environmental factors. Artificial selection of a wing form combined with manipulation of environmental conditions allows to analyze the genetic bases of both wing-form determination and response to environment. The male and female frequently differ from each other in the incidence of different wing forms partly because of the reproductive benefit derived from wing stridulation in the male. A singing male usually overlaps the right forewing on the left, and this stabilized position leads to functional, and hence structural, asymmetry in sound production. Although all the monophyletic existing species of crickets have been evolving over the same evolutionary time of more than 100 million years, they represent remarkably variable stages of retrogressive evolution of the unused stridulating file on the left forewing. We may infer that different species have different rates of retrogressive evolution. Why? To tackle this question is to approach one of the key problems – how the speed of evolution is determined.

c – Special Lecture

METHODS THAT WERE USED BY THE ANCIENT EGYPTIANS FOR THE STORAGE, PRESERVATION, AND CONTROL OF STORED PRODUCTS. M.S. Tadros (Egypt)

d – Morphology Award Lecture

WHAT IS MORPHOLOGY ? J. Chaudonneret, Laboratoire de Biologie Animale et Générale, Université de Dijon, 6, Bd Gabriel, 21100 Dijon, France.

Morphology is not a simple description of anatomical forms, but their interpretation from the standpoint of the dynamic of their phylogenesis. It attempts to draw a detailed basic architectural plan of a Class. This can be achieved through an extremely accurate study of all the external and internal anatomical components, of their working, through the comparison with the architecture of the most primitive representatives of the Class, and through the determination of homologies. The above mentioned basic architectural plan is indispensable for interpreting the forms and structures of the higher representatives of the Class.

The results obtained in this way, and the critical study of descriptive and experimental embryological data enable the morphologist to reconstruct the phylogenetical origin of the basic plan, its evolution within the Class studied.

If similar works are carried out concerning the other Classes of the phylum to which they belong, one can hope to assign the right place to each Class within the evolution of this phylum.

e – Morphology Award Lecture

INSECT CELLS FOR THE STUDY OF GENERAL PROBLEMS IN BIOLOGY. Michael Locke, Department of Zoology, University of Western Ontario, London, Canada N6A 5B7.

A central problem in biology concerns the mechanisms by which linear nucleic acid codes are translated into the three dimensional dynamic architecture of cells. The contents of cells are restricted in their movement by skeletons in their nuclei and cytoplasm. Every cell has an individual arrangement of skeletal components, which vary in time and space while maintaining shape, internal order and mechanical continuity with neighbouring cells. The precise pattern is realized by gene products that self assemble at organizing centers oriented by delicate local stresses. However, the epidermis of caterpillars shows that other factors may contribute to skeletal patterns. The epidermis of caterpillars is composed of syncytial cell doublets formed by the retention of midbodies from mitosis to mitosis. It is an epithelium of siamese twin cells. The interesting feature of these twins is that they have similar or even mirror image nuclear and cytoplasmic patterns. In most cells, sibling similarities are too short lived to be noticed. In twin cells, the structural similarities are conserved long enough for their recognition and study. This paper explores the nature of this transient inheritance of pattern.

f – Film

VIBRATORY COMMUNICATION AND MATING BEHAVIOR OF PLANT- AND LEAFHOPPERS (HOMOPTERA-AUCHENORRHYNCHA). H. Strübing, Institute for General Zoology, Free University of Berlin, Königin-Luise-Str.1-3, 1000 Berlin 33.

Some technique remarks concerning the 16 mm film: A new transducer system enables synchronous recording of behavior in connection with vibratory signals by which these insects are lead together to copulation. This new method for registration shows the free moving leaf- and planthoppers in their normal behavior. A small magnet is fixed on the plant, and a tiny coil is positioned as closely as possible to the magnet without touching it. The voltage induced in the coil by the movements of the magnet is generally proportional to the displacement velocity of the vibrating substrate. It is not necessary to use an additional preamplifier. Therefore this inductive transducer is very suitable for recordings of low-amplitude vibrations making them audible for our ear. It can join directly to the input for low impedance microphones of a tape recorder and it is also very useful for investigations in the open field.

HABITS AND HABITATS OF EARLY HEMIPTERA. C. W. Schaefer, Department of Ecology and Evolutionary Biology, The University of Connecticut, Storrs, CT 06268, U.S.A.

A survey of the major hemipteran groups, and of the groups related to the Hemiptera, suggests that early hemipterans lived on or in the ground. At first general scavengers, these hemipterans soon divided into two (or more?) groups: one specialized on dead and dying arthropods as food; the other(s?) on those parts of plants on, near, or under the ground (roots, stems, fallen seeds, spores). From the former group arose the Heteroptera, some members of which have secondarily become phytophagous. From the latter group arose the exclusively phytophagous Homoptera.

EVOLUTION OF THE ABDOMEN IN THE HEMIPTERA. M.H. Sweet. Department of Biology, Texas A&M University, College Station, Texas 77843.

In Homoptera with a sclerotized abdomen, including the Peloridiidae, the tergum is large, the sternum small, and the abdominal spiracles usually borne on distinct ventral pleural sclerites. In the suborder Heteroptera, in contrast, the tergum is small, the sternum large, and primitively there were dorsal and ventral laterosclerites with the spiracles located on the ventral sclerites. Also, dorsal abdominal nymphal scent glands were present. From this basic abdominal condition which is found in some members of all the infraorders except the Leptopodomorpha and Gerromorpha, six other abdominal patterns may be derived. The loss of ventral connexival sutures characterizes the Leptopodomorpha, the Gerromorpha and some Cimicomorpha. Other Cimicomorpha have lost the dorsal sutures as well. Extensive segmental unions and fusions further characterize the unique highly derived abdominal structure of Gerromorpha. In the trichophoran Pentatomomorpha the originally ventral sclerites have evidently become the dorsal connexivum and the dorsal sclerites, the inner laterotergites. This dorsalization of the pleural sclerites helps explain the variable and frequently dorsal spiracle positions in Lygaeoidea.

EGGS OF LAND HETEROPTERA AND THEIR RELATION TO THE EVOLUTION OF THE GROUP. M. Javahery, Department of Entomology and Lyman Entomological Museum, Macdonald College of McGill University, Que., Canada H9X 1C0.

The structure and biology of eggs, combined with comparative studies of reproductive and genital systems of male and female terrestrial Heteroptera have great significance in higher classification and evolution. Although there is no general agreement regarding existing hypotheses¹ in determining the ancestry of these bugs, a study of the above systems using both conventional and new characters explains much in making it possible to unravel evolutionary trends.

SOUND PRODUCTION IN HETEROPTERA: EVOLUTIONARY SIGNIFICANCE. M. Gogala, Museum Nat. Hist. Slovenija, Prešernova 20, YU-61001 Ljubljana (Yugoslavia)

Sound production evolved in Heteroptera independently many times at least according to the old assumptions. Stridulatory structures were found in certain groups of terrestrial and aquatic bugs on many parts of the body. Newer investigations of acoustic and vibratory communication in land bugs have shown that the first abdominal terga form a basic vibration producing apparatus, found in many groups of Heteroptera (*Pentatomidae*, *Coreidae*, *Lygaeidae*, *Reduviidae* etc.). Such a device is a simple form of a tergal tymbal and it produces low frequency vibrational signals, which are mainly substrate borne, and were often neglected in the past in studies using microphones. A very similar and most probably homologous structure has been described in many primitive Auchenorrhyncha and it therefore seems to be an old acquisition in the evolution of Hemiptera. Supplementary stridulatory structures evolved in many groups of land bugs on various parts of the body, often associated with a tergal tymbal. Particular stridulatory structures are often a characteristic of smaller systematic groups. There has been no evidence of tergal tymbal in aquatic or semiaquatic Heteroptera until now, probably due to physical properties of water.

ATTRACTANT PHEROMONES IN HOMOPTERA AND HETEROPTERA. J. R. ALDRICH, USDA-ARS, Beltsville, MD, USA 20705.

In 1977, identification of norsesquiterpenyl acetates from pygidial glands of California red scale (*Diaspididae*) females signaled the coming-of-age for hemipteran pheromones. Yellow scales liberate a corresponding sesquiterpenyl acetate and white peach scales produce a propionate with an isomeric alcohol. San Jose scales emit monoterpenyl propionates, and female Comstock and citrus mealybugs (*Pseudococcidae*) attract males with monoterpenyl acetates. 1987 marked the first elucidation of an aphid sex pheromone; vetch aphid oviparae release a synergistic mixture of nepetalactone and the monoterpeneol from the hind tibiae. In 1984 the first heteropteran attractant was reported; males of the predatory pentatomid *Podisus maculiventris* (*Asopinae*) produce R-(+)-alpha-terpineol and (E)-2-hexenal from glands opening underneath the wings. *P. fretus* males call mates with S-(+)-linalool and (E)-2-hexenal. Some asopine males secrete 6,10,13-trimethyltetradecanol and/or the isovalerate onto sternal setae. *Stiretrus anchorago* aggregated to the synthetic racemic norterpeneol. *Nezara viridula* (*Pentatominae*) males secrete an attractant from the sternal epidermis including (Z)-alpha-bisabolene and epoxide derivatives. Pheromone strains exist based on trans-/cis-epoxide ratios, and male *Acrosternum* spp. produce distinctive ratios of these epoxides. Female mirids attract flying males with unknown pheromones.

EVOLUTION OF DIVERSITY IN THE SCENT GLAND SYSTEM OF THE HETEROPTERA. B.W. Staddon, Zoology Department, University College, P.O. Box 78, Cardiff CF1 1XL, Wales, U.K.

Major variations illustrating morphological and biochemical evolution in the scent gland system of the Heteroptera are described. Clues to the epigenetic mechanisms by which morphological diversity has been achieved have been sought in studies made of the development and developmental fate of the scent glands in the milkweed bug, *Oncopeltus fasciatus*.

PATTERNS OF REPRODUCTIVE BEHAVIOR IN THE HEMIPTERA. Robert L. Smith, Department of Entomology, University of Arizona, Tucson, Arizona, U.S.A. 85721.

All aspects of hemipteran reproductive behavior including: sexual signals, mate location, mate choice, courtship, genitalic diversity, copulation, sperm competition, oviposition, and parental care are assembled and tabulated from the literature and evaluated in an effort to discover how morphological, physiological, and behavioral preadaptations and constraints as well as sexual selection and ecological pressures may have shaped the diverse reproductive patterns found in this major insect order.

FUNCTIONAL WING MORPHOLOGY IN HEMIPTERA. R. J. Wootton, Department of Biological Sciences, University of Exeter, Devon, U.K. EX4 4PS.

High speed cinematography of a range of Hemiptera in free flight, combined with detailed studies of wing morphology, have done much to clarify the functional significance of wing characters: shape; the patterns of veins and flexion-lines; the hemielytron. It is now possible to recognise and explain certain trends in wing form and flight pattern, and to make some sense of convergent adaptations.

SIGNIFICANCE OF EMBRYONIC EVENTS AS CLUES TO EVOLUTIONARY TRENDS IN HETEROPTERA. H. Mori, Department of biology, Kyorin University School of Medicine, Mitaka-shi, Shinkawa, Tokyo, 181, Japan.

Basic developmental program is a concept introduced to consider evolutionary trends in Heteroptera and related insect groups. This program indicates sequence of the embryonic events to be observed in the ancestral form of specific insect group; evolution occurred in the insect group brings about modifications of the program and results in structural changes within the embryo. In Heteroptera extreme concentration in the ventral nerve ganglia and convolution in the elongating anterior portion of the proctodaeum are noteworthy modifications of the basic developmental program; these could be considered as derived characters. Author also discusses usefulness of embryological information to consider evolutionary trends in insect groups at higher category.

CRETACEOUS HOMOPTERA FROM BRAZIL: A TEST OF CLADISTICS. K.G.A. Hamilton, Biosystematics Research Centre, CEF, Ottawa, Ontario, Canada K1A 0C6.

Whole specimens of Lower Cretaceous Homoptera indicate that modern body forms were present in the most ancient lineages of Cicadellidae; that Cicadoidea and Aleyrodoidea are the sister-groups of Membracoidea and Fulgoroidea; and that the common ancestors of Delphacidae, Cixiidae, Meenoplidae and Kinnaridae had characters now found in none of these families. Many predictions about the origins and ancestors of Homoptera (based on cladistic analysis) are false due to parallel developments and characters obscured by degeneracy. This uncertainty factor makes it impossible to distinguish most paraphyletic taxa from holophyletic ones.

ROLE OF POLYPLIIDY IN THE EVOLUTION OF THE HEMIPTERA. D.B. Thomas, Jr. ARS, Screwworm Research, USDA-AG/SEA (Tuxtlal), P.O. Box 3149, Laredo, TX 78041, USA.

The occurrence of polyploidy in the Insecta is generally associated with parthenogenesis. This is because of problems in resolving sex determination when multiple sex chromosomes are present. The Heteroptera avoid this problem because the sex chromosomes are post-reductional. Thus, polyploids originating from non-reduced gametes, are normally polyploid only for the autosomes. Although there are only a few cases of tetraploid species, mainly in the Pentatomidae, indicating that this is not a common mode of speciation in the Hemiptera, there are several examples of genera, (*Berytinus*: Berytidae; *Lopidea*: Miridae), subfamilies (Scaptocorinae: Cydnidae) and even families (Miridae) that may have originated as polyploids. Thus, polyploidy may be an important macroevolutionary path in the Heteroptera. More controversial, but increasingly plausible, are several tantalizing cases of putative triploidy among the Lygaeidae.

THE ORIGIN AND RADIATION OF THE GERROMORPHA (HEMIPTERA-HETEROPTERA). N. Møller Andersen, Zoological Museum, University of Copenhagen, Universitetsparken 15, DK-2100 Copenhagen, Denmark.

The comparative morphology of the semiaquatic bugs (infraorder Gerromorpha) is relatively well explored through the works by Cobben (1968, 1978) and Andersen (1982), who also presented a cladogram of relationships between the eight gerromorphan families. More recently, the work by Hemming-van Battum and Hemming (1986) on the female reproductive system in *Hebrus* spp. (Hebridae), have significantly improved the understanding of the evolution of the unique reproductive system in gerromorphan bugs.

The phylogeny of the Gerromorpha is reconsidered based on recent findings and the results of numerical cladistic analyses using Wagner parsimony methods. The monophyletic status of the infraorder is supported. So is the hypothesis of the Gerromorpha as sister group of all other heteropterous bugs except the Enicocephalomorpha and Dipsocoromorpha. Despite new interpretations of some characters of the Mesoveliidae, this family still holds the position as sister group of all other gerromorphan families. The separate status of the Hermatobatidae is maintained. Finally, the phylogeny of the Gerridae is discussed.

THE ORIGIN AND RADIATION OF THE AUCHENORRHYNCHA. H. D. Blocker*, Department of Entomology, Kansas State University, Manhattan, KS 66506, USA and M. Asche, Fachbereich Biologie-Zoologie, Philipps-Universität Marburg, D-3550 Marburg, W. Germany.

A historical review of the relationships of the families of Auchenorrhyncha following the views of some of the major Auchenorrhyncha workers will be presented. A selected phylogeny will be presented and contrasted to other suggested phylogenies. Speculative as well as substantiated ideas on the origin and dispersal of the group will be addressed. In addition, ideas on the origin and dispersal of subgroups of some of the major families will be presented.

THE SCALE INSECTS: A DAY AFTER. J. Koteja, Poland.

No Abstract

ORIGIN AND EVOLUTION OF AUCHENORRHYNCHA BASED ON FOSSIL EVIDENCE. D.E. Shcherbakov, Paleontological Institute, Moscow 117868, USSR.

Hemiptera and Psocoptera arose separately from extinct Hypoperlida. First hemipterans, Archescytinoidea (P₁₋₂*), gave rise to Psyllomorpha and Auchenorrhyncha. The latter appeared in P₁ as small hoppers with all essential features of suborder, hind tibial and tarsal pectens with macrosetae (inherited from archescytinids), Y-vein on clavus and head of fulgoroid proportions (small postclypeus faced subventrally, lateral ocelli near eyes), but their flat (non-jumping?) nymphs looked like peloridiid ones. Fulgoromorpha, comprising Fulgoroidea (oldest family - Surijokocixiidae P_{2-J1}) and probably Coleoscytoidea (P₁₋₂), separated from Cicadomorpha in P.

Initial group of Cicadomorpha, Prosbolioidea (P_{1-J3}), gave rise to 5 hemipteran lineages. Ingridae (P₁₋₂) were ancestral to (1) Coleorrhyncha (see Popov, Shcherbakov in this volume) and (2) Scytinopteroidae (P_{2-K1}) with costal fracture and associated tegminal structures, retained by their descendants Heteroptera (T_{3-R}). (3) Large polyneurous Pereborioidea (P_{2-T3}) originated from Prosbolioidea (P₁₋₂). Prosbolioidea (P₂) were ancestral to (4) another group of large cicadas, Palaeontinoidea (P_{2-K1}), and (5) the most prolific stock, Clypeata, with Y-vein on clavus obscured (retained in nymphal wing-pads), postclypeus hypertrophied (initially xylem-feeders?) and lateral ocelli shifted to median one. Early Clypeata (Hylicellidae etc. T_{3-K2}) gave rise to Cicadoidea (T_{3-R}), Cercopoidea (J_{1-R}) and Cicadelloidea (J_{2-R}). First cercopoids (Procercopidae J_{1-K2}) and cicadelloids (Karajassidae J₂₋₃) still retained median ocellus, segmented antennal flagellum and complete hindwing venation. All Cenozoic Auchenorrhyncha belong to recent families, some of them known since J₁ (Tettigarctidae) or K₁ (Cixiidae, Achilidae, Cicadellidae, Aphrophoridae). Fossil membracids are still unknown.

* P-Permian, T-Triassic, J-Jurassic, K-Cretaceous, R-Recent.

ORIGIN OF COLEORRHYNCHA BASED ON FOSSIL EVIDENCE. Yu.A. Popov and D.E. Shcherbakov, Paleontological Institute, Moscow 117868, USSR.

Coleorrhyncha comprise small flattened Hemiptera with tegmina (in macropterous forms, including all fossils) overlapping apically in repose (left tegmen always superior) and flat non-jumping nymphs. Oldest members of suborder, Progonocimicidae (Late Permian - Late Cretaceous of Eurasia, Africa and Australia) are related to one of the most archaic auchenorrhynchan families, Ingridae (Cicadomorpha Prosbolioidea). Both groups have similar head structure, venation (but in ingrids tegmina not overlapping) and flattened habitus with paranotal expansions on pronotum. Ingridae acquired wing coupling apparatus of almost a heteropterous type and were ancestral to Coleorrhyncha and scytinopteroid ancestors of Heteroptera.

Adult Progonocimicidae were apparently able to jump: at least in Cicadocorinae (Early Jurassic - Early Cretaceous) metathorax with large membranous fenestra in front of coxae, stout hind legs with 2 lateral tibial spurs and apical pectens. More flattened Progonocimicinae (Middle Triassic - Late Jurassic) have antennae modified in a peloridiid manner and are, judging from venation, ancestral to Peloridiioidea.

Peloridioids are characterized by enlarged basal cell in tegmen, absence of closed cells in hindwing, very flattened habitus and head usually with a pair of areolae. Mesozoic Karabasiidae contain 2 subfamilies, nominative one (Early Jurassic - Late Cretaceous of Asia) with simple tegminal venation and paranota together with precostal carinae sometimes areolate, Hoploridiinae (Early Cretaceous of Siberia) with venation reticulate. Their jumping abilities reduced, but in Karabasia hind tibia and first 2 of 3 tarsomeres remained swallow-tailed. Modern Peloridiidae are undoubtedly related to karabasiids, although Cenozoic fossils are still unknown.

PALEONTOLOGICAL SUCCESSION OF THE HYMENOPTERANS. A.P. Rasnitsyn, Paleontological Institute, Acad. Sci. USSR, 117868 Moscow, USSR.

The oldest hymenopterous insects known from the Upper (or, possibly, Middle) Triassic all belong to Xyelidae. Early in the Jurassic various Siricomorphs and the first parasitic family Karatavidae appeared. Later in the Jurassic there appeared a variety of phytophagous groups, including the ancestral Tenthredinoid family Xyelotomidae, also the parasitic groups Parorysidae, Ephialtitidae, lower Evanioidea, Ceraphronoidea, Proctotrupoidea, as well as the ancestral Vespomorph family Bethylonomidae. Early in the Cretaceous Tenthredinidae, Ichneumonidae, Cynipoidea, higher Evanioidea, Ceraphronoidea and Proctotrupoidea s.l. have appeared, as well as the aculeate wasps Bethylidae, Chrysididae, Dryinidae, Sphecidae s.l., Pompilidae, Scoliididae and Vespoidea. Ants and Chalcidoids enter the paleontological record near the middle of the Cretaceous, bees during the Eocene. Ant abundance has reached its present level in two steps, the first during the Early Eocene (affecting Dolichoderinae and Formicinae), the second during the Miocene (affecting Myrmicinae and Formicinae).

HOST SPECIFICITY AND EVOLUTION OF THE TELENOMINAE (HYMENOPTERA: SCELIONIDAE). N.F. Johnson, Department of Entomology, The Ohio State University, 1735 Neil Avenue, Columbus, Ohio 43210, U.S.A.

The species of Telenominae are all parasitoids of the eggs of other insects. Their hosts include species in the orders Hemiptera, Homoptera, Lepidoptera, Diptera, and Neuroptera. Individual species range from being oligophagous to polyphagous; in no known case are hosts in more than one order successfully parasitized. The plesiotypic host order is Hemiptera; taxa have twice shifted to parasitize the eggs of Homoptera; once each to Lepidoptera and Diptera; and at least twice to Neuroptera. The roles of host-finding mechanisms in determining species host-ranges and in speciation are described.

A new classification of the Telenominae is proposed. The genus *Telenomus* Haliday is demonstrated to be polyphyletic; *Phanuromyia* Dodd is characterized; the genera *Psix*, *Paratelenomus*, *Nirupama*, and an undescribed genus from Australia form a monophyletic group that is the sister-group of all other telenomines; *Trissolcus* is a paraphyletic assemblage and suggestions for subdividing it are proposed. The sister-group of Telenominae is the newly described genus *Archaeogryon* Galloway & Masner.

THE PHYLOGENY OF THE SUBFAMILIES OF BRACONIDAE (HYMENOPTERA) IN RELATION TO BIOLOGY. C. van Achterberg, Rijksmuseum van Natuurlijke Historie, Postbus 9517, 2300 RA Leiden, Netherlands.

The phylogenetic relationships of the subfamilies of Braconidae are far from well-known and non-physical characters may play an important role in establishing the correct cladogram. Parallelism in these is a serious problem though, so that a large variety of other characters as well is needed. Some particular behavioral and developmental characters are described and their use in the phylogenetic analysis is discussed.

NEW INSIGHTS FOR THE PHYLOGENETIC RECONSTRUCTION OF SYMPHYTA AND THE ORIGIN OF APOCRITA (HYMENOPTERA). G.A.P. Gibson* and H. Goulet, Biosystematics Research Centre, Agriculture Canada, K.W. Neatby Bldg., Ottawa, Ontario, Canada, K1A 0C6.

An important aspect of a cladistic analysis is the study of character states in out-groups. Proper understanding of relationships between outgroups and the group under study is crucial in recognizing polarities. A goal is to reconstruct an ancestor. Such questions are discussed almost daily among hymenopterists. Because of this, most hymenopterists when discussing major lineages turn to Symphyta. Traditionally Cephidae were looked upon as the sister group of all apocrita. Our character analysis does not support this position. A study of old and new character states are bringing new insights not only on major symphytan lineages, but also about the sister group to apocrita.

REPRODUCTIVE STRATEGIES IN TACHINIDAE AND THEIR EFFECTS ON HOST-PARASITOID RELATIONSHIPS. D.M. Wood, Biosystematics Research Centre, Agriculture Canada, Ottawa, K1A 0C6.

By outgroup comparison with most other calyptrate Diptera, the ancestral tachinid probably possessed a simple common oviduct, unmodified for retention of eggs during embryony. A few taxa of Tachinidae (Phasiinae, Exoristini, Winthemiini, some Blondelliini) retain this condition, ovipositing one egg at a time, on, or under, the skin of the host. Subsequent enlargement of the common oviduct as an ovisac or uterus for retention of eggs until they are ready to hatch must have been an important evolutionary event, allowing for a further modification, the broadcasting of eggs in a suitable habitat without actual contact with the host. By leaving host location to her newly hatched larvae, or to chance encounter, a female might infect a new range of hosts formerly unavailable to her.

The three remaining subfamilies of Tachinidae (Tachiniinae, Dexilinae, and Conilinae) each show among their members a transformation series from host contact to broadcasting. Host shifts, to different orders, and rarely even to noninsects (centipedes, arachnids) are most dramatic among those taxa which broadcast their eggs. This suggests that broadcasting, by itself, may favour broader host transfers than might otherwise occur by female choice.

PATTERNS IN THE BIOLOGY OF MUTILLIDAE (HYMENOPTERA) AND THEIR RELATIVES; Denis J. Brothers, Department of Zoology & Entomology, University of Natal, Pietermaritzburg, 3200 South Africa.

The Mutillidae is a large cosmopolitan family of wasps in which the females are invariably wingless and the males almost always winged. They develop as ectoparasitoids of the enclosed immatures of other insects. The size of the adult depends on the amount of food consumed by the larva. These characteristics impose limitations on dispersal and host spectrum which are overcome in different ways within the family. These are reviewed and compared with the situation in the most closely related families, Sapygidae and Tiphiidae.

Efficient dispersal may be unnecessary where hosts are clumped, but may be facilitated by phoresy of the female by the male, especially where there is considerable sexual dimorphism in size, perhaps from the use of different-sized hosts. There is indirect evidence that ants may sometimes be involved here. Development of more than one individual per host is advantageous where hosts are highly scattered, but rarely occurs. The origins of the rather wide host spectrum (cockroach oothecae to bee pupae) may lie in the advantages of utilizing enclosed hosts.

PHYLOGENY AND BIOLOGY OF THE BRACONIDAE (HYMENOPTERA), WITH THE INTRODUCTION OF TWO NEW FAMILY CONCEPTS. M.J. Sharkey, Agriculture Canada, Biosystematics Research Centre, Ottawa, Ontario, Canada, K1A 0C6.

The phylogeny of the basal lineages of the Braconidae is investigated. Based on a number of morphological and behavioural synapomorphies two major clades are elucidated. One of these includes the Betylobraconidae, the traditional "cyclostomes" (Braconinae, Doryctinae and Rogadinae s.l.), and the Opiinae and Alysiinae s.l. The other lineage includes all other Braconidae s.l. It is proposed that these lineages be recognized as separate families. The biologies of these clades are discussed in a phylogenetic context.

HYMENOPTERAN PROFILES IN TEMPERATE AND TROPICAL LATITUDES. R.R. Askew, Dept. of Environmental Biology, University of Manchester, Manchester M13 9PL, England.

Regional variation in the relative abundance and species diversity of groups of Hymenoptera are examined by comparing Malaise trap samples from a number of countries but primarily from England, France and Sulawesi. Samples from a single country vary with trap position and season, but the data permit a number of generalisations. Parasitica are the numerically dominant group in all samples but the Ichneumonidea: Chalcidoidea ratio declines from temperate to tropical latitudes, and representation of Proctotrupoidea, although more erratic, also tends to diminish with latitude. Species diversities mirror the pattern of relative abundance, being high for temperate Ichneumonidea and tropical Chalcidoidea. Separate families of Chalcidoidea, however, vary in their conformity to the general pattern of the superfamily. This variation is explained in terms of the typical host relationships of each family. Existing hypotheses on the so-called anomalous geographical pattern of parasitoid diversity are examined.

HOST RANGE AND THE EVOLUTION OF THE BRACONINAE

(HYMENOPTERA: BRACONIDAE). D.L.J. Quicke, Department of Zoology, University of Sheffield, Sheffield, U.K., S10 2TN.

The vast majority of genera of Braconinae are ectoparasitoids of concealed Coleoptera larvae. The most primitive groups primarily attacked wood boring Coleoptera such members of the Cerambycidae whereas the more highly evolved tribes attack a wider range of hosts, and have moved away from wood to other microhabitats such as galls, grass stems, seed pods, flower buds etc. The greatest degree of host diversity is displayed by the Braconini, one subtribe of which, the Aspidobraconina, have adopted an endoparasitic mode of life attacking exposed butterfly pupae.

The Braconinae is most diverse in the Old World tropics, and it is there that the most advanced host associations are found. Neotropical genera are primarily coleopterous parasitoids - a mode of life which reflects their early isolation from the Old World stock.

The Braconini is most diverse in the Indo-Australian region where several genera have specialized on unusual host groups, e.g. hispid beetles and gall-forming Diptera. No such diversification appears to have occurred within the Neotropics which has a relatively depauperate braconine fauna.

HOST RELATIONSHIPS AS A MEANS OF DEFINING OPIINE AND ALYSIINE BRACONIDAE. R.A. Wharton, Department of Entomology, Texas A&M University, College Station, Texas, U.S.A. 77843.

The Opiinae and Alysiinae are two of the largest subfamilies of Braconidae, together comprising about 2500 described species. Confirmed host records indicate that they are exclusively endoparasitoids of cyclorrhaphous Diptera. The only other Braconidae consistently reared from Diptera are ectoparasitic. Genera and species groups within these subfamilies can often be defined on the basis of their host preferences. However, there are some notable exceptions. The Opiinae are primarily parasitoids of Tephritidae and Agromyzidae. Dacnusine Alysiinae mainly utilize Agromyzidae as hosts. Members of the Alysiini attack a wide variety of hosts, but many of them are known only from the Calyptratae.

THE RELATIONSHIP OF BIOLOGICAL FACTS TO PHYLOGENETIC FANTASY IN THE TORYMIDAE (HYMENOPTERA). E.E. Grissell, Systematic Entomology Laboratory, BBI, Agricultural Research Service, U.S.D.A., c/o U.S. National Museum NHB 168, Washington, D.C. 20560. U.S.A.

This paper addresses two questions: 1) are biological observations necessarily factual? and 2) what do they mean in terms of torymid phylogenetics? Three broad types of host association are found in Chalcidoidea, but Torymidae is unusual in having numbers of species in all three categories. These associations are: phytophagous and/or carnivorous, parasitic and/or predaceous, primary and/or secondary. These associations are explained with examples from the 3 torymid subfamilies: Megastigminae, Monodontomerinae, and Toryminae. It is difficult to assess host relationships accurately because most biological records are based upon emergence from "host-material" and not from actual host dissections. With a few notable exceptions, torymid host data appears to have little correlation with current phylogenetic hypotheses. This may be due in part to both inadequate biological data and phylogenetic hypotheses, or it may be a result of the apparently generalist feeding habits of Torymidae.

PECULIARITIES OF PARASITISM OF CHALCID WASPS (HYMENOPTERA, CHALCIDOIDEA) ON THEIR HOST EULECANIUM DOUGLASI SULC IN THE SUBARCTIC; E.S. SUGONYAEV*, N.D. Voinovich, Zoological Institute Academy of Sciences, 199034, Leningrad, USSR.

A two-year generation of E. douglasii under subarctic conditions determined by rigorous climate is a source of periodic fluctuations recourses to be available for parasites which put the serious problem for the letter because they have not possibility to parasitize the same host stages every year. There are several adaptive strategies for survival of parasites. The conformist Coccophagus aterrimus solves that problem owing to forming of particular kind of the 1st instar larva which diapauses in host larva for almost two years. The regulator Encyrtus infidus accelerates a metamorphosis of infested host with the result that the letter turns into a female in one year. Blastothrix trjapitzini and Plesiomicroterys speciosus form specific behaviour adaptations. The former has unspecialized response on age structure of host population. The latter parasitizes during "larval year" extremely not numerous females of so called "alternative population" of host.

PHYLOGENETIC RELATIONSHIPS WITHIN THE ICHNEUMONIDAE (HYMENOPTERA): SIGNIFICANCE FOR UNDERSTANDING BIOLOGY.

D.B. Wahl, American Entomological Institute, 3005 SW 56th Ave., Gainesville FL 32608, U.S.A.

Progress in discovering relationships between subfamilies of Ichneumonidae has been slow. Recent work with the morphology of mature larvae has been combined with adult morphological characters to give a best estimate of the subfamily relationships. This in turn has enabled a minimum estimate of the number of times the endoparasitoid lifestyle has arisen, as well as helping to understand some other aspects of ichneumonid biology. Comparison with the Braconidae leads to the conclusion that ectoparasitism of wood-boring hosts was most probably not the ground-plan biology of the Ichneumonidae.

A PHYLOGENETIC ANALYSIS OF THE SUBFAMILY NOMADINAE (HYMENOPTERA: ANTHOPHORIDAE). Byron Alexander, Department of Entomology, Cornell University, Ithaca, New York, U.S.A. 14853

Cleptoparasitic taxa have arisen independently in many lineages of bees, but the Nomadinae have undergone the most extensive diversification after becoming cleptoparasitic. The reasons for this are obscure, but an understanding of the phylogeny of this group could help in evaluating alternative explanations. A quantitative cladistic analysis using Swofford's PAUP program, with characters derived from adult and larval morphology, found three equally parsimonious cladograms for eleven terminal taxa. Major components in these cladograms were often supported primarily by larval characters, and the topology of these cladograms agrees closely with previous analyses based on larval characters alone. This underscores the potential value of using all stages of the life cycle in cladistic analyses, but also makes it difficult to place taxa known only from adult specimens.

EVOLUTION OF HOST ASSOCIATIONS AND MODE OF PARASITISM IN PERILAMPIDAE (CHALCIDOIDEA). D. Christopher Darling, Department of Entomology, Royal Ontario Museum and Department of Zoology, University of Toronto, Toronto, Ontario, Canada M5S 2C6.

Perilampidae are a small family of parasitic wasps with remarkably diverse host associations; both primary and hyperparasitic relationships are well-established. The approximately 250 species are currently classified in 6 genera, with most of the species referred to the cosmopolitan genus Perilampus. The host data for the five smaller genera indicate conservatism and all known species are primary parasites. Perilampus species parasitize a diversity of hosts, as primary and hyperparasites. To better understand the historical development of parasitism in this family, phylogenetic studies were undertaken using Eucharitidae and Chrysolampinae (Pteromalidae) as outgroups. The analysis indicates considerable host switching and little support for stepwise coevolution of these parasitic wasps during the evolution of holometabolous insects. However, certain species groups of Perilampus are restricted to taxonomically defined host groups and these cases may provide evidence for stepwise coevolution of host and parasite. The hypothesis is developed that hyperparasitism may be responsible for the diversity of host associations found in Perilampus and therefore in the Perilampidae.

THE VARIOUS STRATEGIES FOR HOST UTILIZATION AMONG THE PARASITOID HYMENOPTERA. S. Bradleigh Vinson, Department of Entomology, Texas A&M University, College Station, TX 77843.

The different physiological approaches to parasitoidism among various parasitoid hymenoptera will be examined. Emphasis will be placed on endoparasitoidism within the Ichneumonoidea. The physiological interactions between parasitoids and their hosts differ among several endoparasitoid genera. For example, the polydnviridae associated with the Ichneumonoidea differ both in morphology and their physiological effects, although the physiological systems affected are similar. While the symbiotic polydna viruses are essential to endoparasitoidism in some parasitoid genera, these viruses are absent in other endoparasitoid genera within both the Braconidae and Ichneumonoidea. The physiological relationship between parasitoids and their hosts will be compared among a number of parasitoid genera.

THE KNOWN TYPES OF EMBRYONIC DEVELOPMENT IN ENDOPHAGOUS HYMENOPTERA AS STRATEGIES TOWARD ADAPTATION TO PARASITISM. E. Tremblay, Dipartimento di Entomologia e Zoologia agraria, Università di Napoli, 80055 Portici, Italia.

Adaptation to parasitism in Hymenoptera has required the evolution of external selection processes involved in "host habitat location", "host location", "host acceptance". In the internal environment of their hosts endoparasitoids are faced with "host suitability" problems which elicit physiological adaptations. A variety of types of embryonic development in the most evolved endoparasitoids led to peculiar adaptations for endoparasitic life such as yolk reduction, persistence of serosal envelopes, development of trophamniotic membranes or trophocytes, larval polymorphism and polyembryony. The physiological significance of many end products of complex embryologies is almost unexplored but circumstantial evidence indicates that they evolved as strategies of "host exploitation", which can be defined as the last step in host-parasite relationships.

EVOLUTION OF LIFE HISTORY STRATEGIES IN THE APHELINIDAE.
J.B. Woolley, Department of Entomology, Texas A&M
University, College Station, Texas, U.S.A. 77843

Many species of Aphelinidae display unusual strategies for parasitization in which female and male host relationships differ with respect to host taxa, location of oviposition, and/or mode of development. These phenomena, termed heteronomy, appear to be restricted to three or four currently recognized subfamilies. In some cases, all known species in a genus exhibit heteronomous development, whereas, species in other genera exhibit normal development, either as primary parasites or hyperparasites. Consideration of phylogenetic relationships provides a necessary foundation for the study of the evolution of these phenomena. New hypotheses are provided for the phylogenetic relationships of Aphelinidae based on morphological evidence. Scenarios which have been proposed for the evolution of heteronomy are examined with respect to these phylogenetic hypotheses. It is of particular interest to determine whether these biological phenomena have evolved in a single lineage, or whether convergent evolution in more than one lineage has occurred.

COMPARATIVE BIOLOGY AND PHYLOGENY OF THE
CYCLOSTOME GROUPS OF BRACONIDAE (HYMENOPTERA):
THE POLYPHYLETIC ORIGIN OF ENDOPARASITISM.
J.B. Whitfield, Department of Entomology, The
Ohio State University, Columbus, Ohio USA 43210.

Endoparasitism arose independently at least three times within the cyclostome groups of Braconidae. These three endoparasitic lineages show differences in the form of endoparasitism adopted, that reflect their independent origins. The subfamily Rogadinae, as usually recognized, is a polyphyletic assemblage of tribes, grouped together in part by symplesiomorphies. The subfamily Doryctinae also is unsupported by synapomorphies, and should be re-examined phylogenetically.

THE FUNCTIONAL MORPHOLOGY AND EVOLUTION OF THE
CHRYSIDID CUCKOO WASPS (HYMENOPTERA). L.S. Kimsey
Museum of Comparative Zoology, Harvard University
Cambridge, Massachusetts 02138, U.S.A.

Chrysidid wasps are redivided into 4 subfamilies: Cleptinae, Amiseginae, Loboscelidiinae and Chrysididae. These groupings are based on major changes in morphology, which directly relates to the host taxon parasitized. Cleptinae have the fewest derived features and are the least specialized parasites, attacking prepupal sawflies. Loboscelidiinae and Amiseginae have specialized mandibles and ovipositor segments involved in parasitizing walking stick eggs. The greatest changes have occurred in Chrysidinae, which are nest parasites of bees and wasps. In these wasps the number of external abdominal segments are reduced, tightly fitted and weakly intermusculated, the abdomen is concave ventrally, and the ovipositor is longer, consisting of 4 or more well intermusculated segments. This group has struck a balance between protecting themselves from the adult host, by rolling up in a ball using the abdomen as a shield, and flexibility during oviposition.

OF EUCHARITIDS AND ANTS (HYMENOPTERA): BIOLOGICAL
CONSERVATISM AND MORPHOLOGICAL EXPLOSION. J.M. Heraty,
Department of Entomology, Texas A&M University, College
Station, Texas, U.S.A. 77843

The family Eucharitidae is a small group of parasitic wasps that can be divided into two distinct subfamilies, the Oraseminae and Eucharitinae. Eucharitidae include only species which are specialized parasites of ants. Females oviposit into plant tissue, away from the host, and active first-instar larvae (planidia) seek adult ants, or thrips intermediates, for transport to the ant nest. Methods of oviposition and dispersal of the early stages are diverse. In general, Oraseminae lay single eggs into oviposition punctures in plant tissue and most of the known larvae have been found associated with thrips. Eucharitinae lay their eggs in large masses within existing cavities in plant structures and, at least within advanced groups, there appears to be no thrips association. The morphology of planidia is very conservative within each of the two subfamilies and only minute differences can be found below the generic level. Oraseminae exhibit relatively little divergence in adult morphology and are similar in general appearance to other chalcidoids. In contrast, Eucharitinae have undergone a morphological explosion and show a diverse array of bizarre structures. The phylogenetic relationships of the two subfamilies are discussed and morphological attributes of each are correlated with larval behavior.

CONVERGENT CHROMATIC MIMICRY AMONG SOME NEOTROPICAL
HYMENOPTERA: A SEARCH FOR THE MODEL. L. Masner,
Biosystematics Research Centre, Agriculture Canada, K.W.
Neatby Bldg., Ottawa, Ont., Canada K1A 0C6.

Neotropical members representing nine superfamilies and 15 families of hymenopterous insects display a convergent chromatic pattern with black head, bright red mesosoma and black metasoma (BRB pattern). The pattern is restricted by four factors, viz. the total size of body (4-8mm), spatial distribution (on bushes ca 1-2 m high), altitude (from sea level to 1200 m sharp) and geography (tropical Central and South America, incl. the Caribbean). No single apparent stinging model (e.g. ant, wasp), numerically more frequent than the above mimics, was observed. Chemical defence (such as repugnatory glands) making mimics unpalatable to predators (e.g. insects or small vertebrates) is a possibility. Field experiments with members of the most prominent groups (e.g. Scelioninae wasps) are needed to test this hypothesis. The ratio of BRB to all black species among some Neotropical genera of the Scelioninae is often 1:1, in extreme cases 6:1.

INTERRELATIONSHIPS OF BIOCONTROL AND SYSTEMATICS. K.P. Carl*(1) and D.J. Greathead(2), CAB International Institute of Biological Control, (1) CIBC, CH-2800 Delemont, Switzerland, (2) CIBC, Imperial College, Silwood Park, Ascot, Berks SL5 7PY, UK.

Biocontrol, more than any other biological discipline, depends heavily on the expertise of taxonomists and biosystematists, primarily for the correct identification of target pests, insects or weeds, and their natural enemies. To mention but a few other aspects, information on life-histories and biogeography can greatly facilitate the planning and surveys in the right areas at the right time, and predictive classification can help in the study of unknown species.

The systematists derive benefit from biocontrol studies on host associations of natural enemies, the study of immature stages, the provision of series of reared individuals for morphological comparison, and sometimes the detection of cryptic species.

The initiation of an International Advisory Council for Biosystematic Services in Entomology will no doubt lead to an enhancement of cooperation. The International *Heliothis* Biocontrol Work Group and the International *Heliothis* and Natural Enemies Biosystematics Work Group as the first-born children will have the responsibility to demonstrate the validity of this concept.

ECOLOGICAL GENETICS OF *HELIOTHIS ARMIGERA* (HUBNER) AND *H. PUNCTIGERA* WALLENGREN (LEPIDOPTERA: NOCTUIDAE). J.C. Daly, CSIRO Division of Entomology, Canberra, ACT 2601 Australia.

Ecological genetics is a study in natural populations of the pattern of genetic variation and those aspects of a species' biology which influence this pattern.

Electrophoretic variation was studied in 13 populations of *H. armigera* and 6 populations of *H. punctigera* in eastern Australia. There was not a marked geographic pattern to the genetic variation in either species. It was concluded that the consequences of gene flow in the two species was similar although they may differ in their patterns of dispersal.

H. armigera is polymorphic for resistance to synthetic pyrethroids. Monitoring studies suggest that there is homogeneity in the frequency of resistance within a region and that local populations are diluted in springtime by immigration of susceptible individuals. This is expected given the degree of local movement observed to occur in *Heliothis*.

Selection for pyrethroid resistance is dependent on the age distribution of larvae in the crop at the time of spraying and on the pattern of egg-laying on the crop as the pesticide decays or is diluted by plant growth.

MITOCHONDRIAL DNA ANALYSIS IN THE *HELIOTHIS VIRESCENS* COMPLEX. M.D. Huettel, R.W. Poole & C. Mitter (USA).

GENETICAL STUDIES OF *HELIOTHIS VIRESCENS*. David G. Heckel, Department of Biological Sciences, Clemson University, Clemson, South Carolina USA 29634

There are at least two aspects of the control of *Heliothis virescens* (tobacco budworm) for which genetic information is crucial. The genetic basis of insecticide resistance must be understood in order to develop resistance management strategies for this highly adaptable pest. The genetic basis of hybridization-induced male sterility must also be understood if similar autocidal control systems are to be engineered for other species of the genus. Our goal is to develop a genetic linkage map and marker strains for *H. virescens* to facilitate the study of these questions. We will review 1) our progress in linkage mapping and strain construction using allozymes and DNA RFLPs as marker loci, 2) our preliminary investigations of the inheritance of pyrethroid resistance, and 3) the potential for application of these genetic tools in obtaining a clearer picture of population differentiation within the species, and of the biosystematics of the genus.

HYBRIDIZATION STUDIES IN THE *HELIOTHINI*. R.E. Furr* and N.R. Spencer, United States Department of Agriculture, Agricultural Research Service, Stoneville, Miss. USA.

Genetic control methods offer promise for the suppression of *Heliothis* species. Successful development of backcross sterility in *H. virescens* stimulated research for a similar type of sterility in *H. zea*. The following living *Heliothis* (*Helicoverpa*) species have been imported into the Stoneville Research Quarantine Facility for backcross sterility research with *H. zea*: *H. armigera* (Egypt, 1984), *H. punctigera* (Australia, 1985), *H. armigera conferta* (New Zealand, 1985), *H. armigera* (Zimbabwe, 1986), *H. assulta* (Zimbabwe, 1986), *H. fletcheri* (Mali, 1986), *H. gelatopoeon* (Argentina, 1986), *H. assulta* (Thailand, Pakistan and Indonesia, 1987), and *H. armigera* (Thailand, Pakistan and Indonesia, 1987). Results from these tests indicate that *H. punctigera* and *H. gelatopoeon* are reproductively isolated from *H. zea*. Mating and reproduction have been obtained from *H. armigera conferta*, *H. armigera* and *H. fletcheri* females mated with *H. zea* males. Intermatings with *H. assulta* are still under way. Some individual matings with the above species have indicated sterility. This detected sterility is not thought to be usable in a control program however, research is continuing to identify a type of biological sterility in *H. zea* for use in conjunction with the backcross sterile *H. virescens*.

STATUS AND PROSPECTS FOR GENETICALLY-ENGINEERED ARTHROPOD NATURAL ENEMIES. M.A. Hoy*, Department of Entomology, University of California, Berkeley, California 94720.

Genetic manipulation of arthropods by artificial selection, hybridization, or recombinant DNA (rDNA) techniques will be reviewed to determine their current status and the prospects for improving biological control in agricultural IPM systems. Pesticide resistance has been developed through artificial selection in a predatory mite (*Metaseiulus occidentalis*), the common green lacewing (*Chrysoperla carnea*), and, recently, in two parasitoids (*Aphytis melinus* and *Trioxys pallidus*). These projects are at different stages of development and implementation. The potential for rDNA technology will be discussed, with consideration of the scientific and regulatory issues that this methodology raises. Attributes other than pesticide resistance could be manipulated once we can identify desirable traits.

No Abstract

THE ROLE OF SYSTEMATICS IN INTRODUCTION OF EXOTIC SPECIES OF NATURAL ENEMIES. J.E. Powell*, USDA, ARS, Insect Rearing Research Unit, Mississippi State, Mississippi 39762-5367 and J.R. Coulson, USDA, ARS, Beneficial Insects Laboratory, Beltsville, Maryland 20705.

The crucial role of systematics in classical biological control programs is expressed from the perspective of biocontrol specialists. Natural enemy identifications are desirable before they are sought, but this often is impossible. Even after they are collected and reared, projects may be hindered because certain natural enemies must remain in a quarantined status until thorough taxonomic studies are conducted. Specific cases will be emphasized which demonstrate the need for strong systematic/taxonomic support in biological control. Elements that impede progress in systematics are described.

PROBLEMS IN THE IDENTIFICATION OF TRICHOGRAMMATIDAE. E. R. Oatman and J. D. Pinto*, Department of Entomology, University of California, Riverside, California 92521, USA.

At least sixteen species of *Trichogramma* and one species of *Trichogrammatoidea* have been recorded as natural parasites of *Heliothis* eggs. Worldwide, eleven species of *Trichogramma* and one species of *Trichogrammatoidea* have been released against *Heliothis* spp., primarily on cotton and tomato. Utilization of trichogrammatids in biological control is complicated by a poorly known fauna, cryptic species, and significant phenotypic plasticity of characters routinely used for identification. These problems are summarized. The effects of different rearing conditions on structures used in the identification of *Trichogramma* are discussed.

BRACONIDAE OF *HELIOTHIS*: STATE OF THE ART. P.M. Marsh, Systematic Entomology Laboratory, U.S. Department of Agriculture, c/o U.S. National Museum, Washington, D.C. 20560, USA.

The Braconidae represent a major source of natural enemies for the biocontrol of *Heliothis*. A discussion is presented on the taxonomic status of species that have been associated or recorded from *Heliothis* species around the World. Suggestions will be presented for studies of new potentially valuable species and future geographical areas to be surveyed for new species introductions.

ICHNEUMONIDAE OF INDIAN *HELIOTHIS*. P.K. Nikam, Department of Zoology, Marathwada University, Aurangabad 431 004, India.

Three *Heliothis* species, *H. armigera* (Hubner), 99.2%, *H. assulta* Geunee 0.6% and *H. peltigera* (Schiffermuller) 0.2% occur in India, of which the first damages 182 and others 7 each cultivated and uncultivated plant species. In India, altogether 93, 13 and 18 parasitoid species have been reared on *H. armigera*, *H. assulta* and *H. peltigera* respectively, of which 24, 2 and 5 belong to Ichneumonidae. Mostly the Ichneumonids are larval parasitoids of *Heliothis* species preferring young, medium to old host instars. Amongst Ichneumonidae, *Porizontine Campoletis chloridae* Uchida, *Eriborus argenteopilosus* (Cameron), *Diadegma* sp. and *D. fenestralis* (Holmgren) parasitize 10-85%, 7-21%, 24-34% and 8-18% *H. armigera* larvae are the promising key parasitoids. In addition, 3 species of Ophionine *Enicospilus* Stephens need exploration for their utility in the biological control of *Heliothis* species in India. Larvae of all the three species of *Heliothis* are parasitized by *C. chloridae*, whereas that of *H. armigera* and *H. peltigera* by *E. argenteopilosus*.

A REVIEW OF THE WORLD SPECIES OF *Telenomus* (HYMENOPTERA: SCALIONIDAE) ASSOCIATED WITH *Heliothis* (LEPIDOPTERA: NOCTUIDAE) AND RELATED GENERA. A. Polaszek, British Museum (Natural History) & F. Bin*, University of Perugia, ITALY

The species of *Telenomus* known to parasitize *Heliothis* and related genera of economic importance are described and figured, primarily to facilitate their identification. Biologies of the species, where known, their distributions and host-associations, are summarized.

The roles of *Telenomus* species as natural enemies and potential biological control agents of heliothine pest species are discussed.

TACHINIDAE OF ORIENTAL *HELIOTHIS*. Zhao Jianming (China).

No Abstract

CRYPTIC SPECIES: DO WE UNDERSTAND THEM?. H.E.H. Paterson, Department of Entomology, University of Queensland, St Lucia, 4067 Australia.

Cryptic or sibling species constitute a considerable problem for mosquito ecologists and other biologists. They are not well understood and opinions differ as to their meaning.

The Biological Species Concept provides little theoretical understanding of this phenomenon. In contrast the Recognition Concept of Species provides basic insights to understanding the nature of cryptic species.

EVOLUTION OF THE YELLOW FEVER MOSQUITO, *Aedes aegypti*: A NEW SYNTHESIS FOR AN OLD ENEMY. W.J. Tabachnick, USDA, Agricultural Research Service, Arthropod-borne Animal Diseases Research Laboratory, P.O. Box 3965, Laramie, Wyoming, USA 82071.

Aedes aegypti is widely distributed throughout the tropical and subtropical world. A variety of studies have demonstrated geographic patterns of variation among natural populations in isozyme genetic markers, vector competence for arboviruses, morphology and behavior. Studies of *A. aegypti* mitochondrial DNA variability provide support for the hypothesis of the recent evolution of the species. The patterns of variation observed in these studies provide a consistent picture of differentiation. This will be summarized and used to advance a hypothesis concerning the origins of *A. aegypti*, its evolution and the probable reasons for its distribution throughout the world.

SPECIES PROBLEMS REVEALED BY CROSSING EXPERIMENTS IN THE GENUS *Toxorhynchites splendens* (DIPTERA: CULICIDAE) GROUP. M. Horio* and M. Tsukamoto, Department of Medical Zoology, University of Occupational and Environmental Health, Yahatanishiku Kitakyushu 807, Japan.

Toxorhynchites splendens is considered to be one of the most useful agents for biological control of aedine larvae, vectors of various diseases. This species is widely distributed in Asian tropical countries. *Tx. amboinensis* closely resemble the former species except that males of the latter have dark caudal tufts on tergite VIII instead of orange one. Reciprocal crosses between strains of *Tx. splendens* collected from India, Sri Lanka, Malaysia, Thailand, Philippines, or Hawaiian strain of *Tx. amboinensis* yielded effective F₁, F₂ and back-cross progenies. However, *Tx. splendens*-like strains collected from Palawan Is. (Philippines) produced no or extremely few progenies by crossing with other strains of *Tx. splendens* or *Tx. amboinensis*. These results suggest that *Tx. amboinensis* should be considered to be a morphological mutant of *Tx. splendens*, and the *Tx. splendens*-like strain (Palawan) might be a distinct species or subspecies.

CHROMOSOMAL EVOLUTION IN THE GENUS *Orthopodomyia* (DIPTERA: CULICIDAE). A. Marchi, Ist. Biol. Gen., Univ. Cagliari, Via Ospedale 119, 09124 Cagliari, (Sardinia) Italy.

Metaphase and polytene chromosomes of the neotropical *Orthopodomyia fascipes* (Thomasina group) and of 4 species of the holarctic *Signifera* group (the palaearctic *Or. pulcripalpis* and the nearctic *Or. alba*, *Or. kummi* and *Or. signifera*) were analyzed using several banding techniques. The chromosome complement of the 5 species (2n=6) was typical of Culicinae. Distribution of heterochromatin in the metaphase chromosomes (C-bands) was similar in the 4 New World species but differed in *Or. pulcripalpis* by the localization of an intercalary band on the shortest chromosome pair (site of a major nucleolous organizer). Bright fluorescent pericentromeric chromatin (A-T rich DNA), detected by staining with DNA specific fluorochromes, also distinguished the European species from the dully fluorescent metaphase chromosomes of the nearctic ones. A few minute, bright fluorescent dots were present in the centromeres of *Or. alba*. These differences were amplified in polytene chromosomes. Bright centromeric dots were detected in the polytene nuclei of *Or. signifera* and *Or. fascipes* but not in *Or. kummi*. A fluorescent banding pattern characterized the polytene arms in *Or. pulcripalpis*. Intraspecific polymorphism of fluorescent bands was discovered, a condition undetected in orcein-stained chromosomes.

CHROMOSOMAL EVOLUTION IN *Aedes* INFERRED FROM LINKAGE HOMOLOGY OF ENZYME LOCI. T.C. Matthews* and L.E. Munstermann, Department of Biology, University of Notre Dame, Notre Dame Indiana.

The study of chromosomal evolution in aedine mosquitoes is based on linkage map comparisons due to the lack of good polytene chromosomes. Enzyme maps are especially useful because of the relative ease of mapping these loci using standard electrophoretic and mating procedures.

Enzyme maps for six groups in four subgenera are compared: *A. (Protomacleana) triseriatus*, *A. (Finlaya) togoi*, *A. (Ochlerotatus) atropalpus*, *A. (Stegomyia) aegypti*, *A. (Stegomyia) albopictus*, and *A. (Stegomyia) polynesiensis*.

The *triseriatus* map, which is based on extensive intra- and interspecific data, is used as a baseline. Map positions and distances from these two types of data were nearly identical. With the exception of the translocation of the sex locus to different chromosomes, linkage homologies between *triseriatus*, *togoi*, and *atropalpus* (Section A species) are conserved. Homologies between *aegypti*, *albopictus*, and *polynesiensis* appear to be highly conserved with no major changes in linkage assignment or order. Differences in linkage associations between Section A and B species can be explained by inversion and subsequent translocation involving chromosomes II and III. These comparisons suggest that chromosome repatterning has played a significant role in *Aedes* evolution.

EVOLUTION OF THE *Anopheles gambiae* COMPLEX AS INFERRED FROM RIBOSOMAL DNA AND MITOCHONDRIAL DNA. F.H. Collins* and S.M. Paskewitz, Malaria Branch, Division of Parasitic Diseases, Center for Infectious Diseases, Centers for Disease Control, Atlanta, GA 30333, U.S.A.

The *Anopheles gambiae* complex (Diptera: Culicidae) is a group of 6 morphologically identical African mosquito species. Previously, the evolutionary relationships of the members of this complex have been inferred from the distribution of fixed and polymorphic inversions present in polytene chromosomes of the ovarian nurse cells. To examine this phylogeny from a molecular perspective, we have studied the ribosomal RNA genes (rDNA) and the mitochondrial genome (mtDNA). Using cloned rDNA and mtDNA of *A. gambiae* as probes, we have mapped restriction enzyme sites in both conserved and variable portions of rDNA and mtDNA in 5 of the species in the complex. Phylogenies inferred from each of these 2 unrelated DNA families are similar, and these phylogenies differ in some important respects from the one derived from polytene chromosome inversions.

EVOLUTION OF MOSQUITO GENOMES. K. S. Rai, Department of Biological Sciences, University of Notre Dame, Notre Dame, Indiana, 46556, U.S.A.

This paper presents data on comparative karyotypes, haploid nuclear DNA amounts, abundance and distribution of families of repeated DNA sequences and molecular organization and evolution of genomes in mosquitoes with particular emphasis on *Aedes*. Except *Chagasia bathana* where $2n=8$, the basic complement in all mosquito species consists of three chromosomes with the smallest chromosome being sex-determining. Extensive variation exists in overall length, morphology, and types and amounts of heterochromatin among various species. The total chromosomal length varies almost five fold. Meiotic chromosome associations in species hybrids and linkage map comparisons indicate extensive structural chromosome repatterning in the form of inversions and reciprocal translocations.

Haploid genome size varies almost 8-fold from 0.245 ± 0.01 picograms of DNA in *Anopheles quadrimaculatus* to 1.902 ± 0.06 picograms in *Aedes zoosophs*. Within the genus *Aedes*, a more than three-fold variation in haploid nuclear DNA amounts exists. In general, DNA amplification accompanies speciation and range extension of certain species. At the molecular level, much inter- and intra-specific variation exists in abundance and distribution of families of repeated DNA sequences and in genome organization. (Supported by NIH grant AI 21443.)

EVOLUTION OF MOSQUITO GENOME UNDER INSECTICIDE SELECTION PRESSURE. N. Pasteur, CNRS/LA327, USTL, Montpellier France.

Mosquitoes are subjected to intensive chemical control worldwide, and many species have developed resistance to pesticides. Little is known on the nature and extent of the genomic modifications that have occurred in the resistant insects. Our joint studies with scientists of INRA/Antibes (France) and UC/Riverside have shown that in three *Culex* species increased detoxication of organophosphates (OPs) by several esterase isozymes is the result of a 10 to 250-fold amplification of the respective structural genes. These genes are included in large genomic segments (up to 20 kb) which are coamplified with the structural genes. Coding sequences of esterase genes seem well conserved among strains (*Sau3A* digestion), whereas the "amplified units" containing them present variations (*EcoRI* digestion). However, "amplified units" in strains with the same isozyme have identical *EcoRI* sites, despite their different geographic origin. The present data suggest that several independent amplification events have occurred, each involving a specific esterase isozyme and a portion of genomic DNA with characteristic *EcoRI* sites. The wide distribution of some amplification systems is probably due to gene flow: high esterase activity in OP-resistant *Culex* is inherited as a single trait which shows that the multiple gene copies observed on the same portion of one of the three chromosomes are inherited as a "unit".

POPULATION GENETICS OF THE MALARIA VECTOR, *ANOPHELES BALABACENSIS* (DIPTERA: CULICIDAE): NO CORRELATION BETWEEN ISOZYMES, HOST-SEEKING AND RESTING BEHAVIOUR. J. Hii*, S. Panyim, M. Chew, Y.S. Vun, M. Nasir, Tropical Diseases Research Center, Department of Medical Services, 88814 Kota Kinabalu, Sabah, Malaysia.

Genetic variability of behaviourally dissimilar subpopulations of the medically important malaria vector, *A. balabacensis* was studied during the beginning of the wet season. One experiment was designed to determine the association between capture and recapture of marked mosquitoes from two unrelated hosts; adult survival and bloodmeal analysis was monitored in marked mosquitoes from recaptured samples. Although the mark-recapture data suggested behavioural heterogeneity between buffalo and man biters, restriction endonuclease fragment length polymorphism analysis revealed similarity in repeat sequence abundance profiles. Southern blot analysis using the probe pMU55 showed successful hybridization with *A. balabacensis*. In another experiment to determine "habitat loyalty" in indoor resting patterns, the adult parity and population genetic data showed no differentiation among the recapture subsamples. It is concluded that intraspecific variation for host-seeking and tendency to rest indoors exert a greater influence than do genetic differences.

RELATIONSHIPS AMONG HATCH DELAY, LIFE HISTORY STRUCTURE AND GENETIC VARIATION WITHIN A POPULATION OF *AEDES TRISERIATUS* (DIPTERA: CULICIDAE). T. Llv Dahl* and R.K. Koenekoop, Department of Biology, Clark University, Worcester, Massachusetts 01610, USA.

Hatch time variation in *Aedes triseriatus* is associated with variation in other life history traits. Positive associations between hatch delay and larval development time, sex, adult size, and larval survival have been reported. In this study, we report associations between hatch delay and genetic variation detected through electrophoretic techniques. More than 4000 larvae hatching from eggs subjected to weekly suboptimal stimuli were raised to adulthood, after which they were analyzed for variation at twelve isozyme loci. Four of these loci were monomorphic. Of the eight polymorphic loci, hatch delay was significantly associated with allele or genotype frequency at five loci (*Idh-1*, *Mdh-2*, *Gpi*, *ME* and *Pgm*). Three polymorphic loci showed no associations with hatch delay. Each of the five loci that were associated with hatch delay also showed significant departures from expected Hardy-Weinberg genotype frequencies, while the genotype distributions of the other three loci were in accordance with expected frequencies. The eight polymorphic loci reveal two distinct patterns when they are pooled into two groups on the basis of their associations with hatch delay. The fraction of heterozygous individuals increases with hatch delay for loci that have allele or genotype frequencies associated with hatch delay; heterozygosity levels show no response for loci that have no significant association with hatch delay.

EVOLUTION OF AUTOGENY. G. F. O'Meara, Florida Medical Entomology Laboratory, IFAS, University of Florida, Vero Beach, Florida USA 32962

In mosquitoes and several other families of hematophagous Diptera, the females of some species can develop an egg clutch on a blood-free diet. This capacity is called autogeny. Usually autogeny is limited to the production of the initial egg clutch, but in a few mosquito species the females develop autogenously repeated egg clutches. With few exceptions, reduced total fecundity and egg clutch size are associated with autogenous mosquitoes. Some mosquitoes are facultative blood feeders maturing the initial egg clutch either with or without a blood meal, whereas others delay blood feeding until the first egg clutch has been laid. Mating and sugar feeding are prerequisites for the expression of autogeny in some species, but not in others. The need for these prerequisites can be dependent upon conditions in the mosquito's aquatic habitat. Within several different groups of freshwater mosquitoes, autogeny is much more prevalent or obligatory in populations occurring at the higher latitudes. Yet, relatively few mosquitoes with piercing mouthparts have totally abandoned the blood feeding habit. The distribution and prevalence of the various feeding/reproductive types have undoubtedly been influenced by ecological factors not only in the mosquito's terrestrial environments, but also in its aquatic habitats.

SWARMING AND MATING BEHAVIOR IN EVOLUTION OF MOSQUITOES. T. Ikeshoji, Department of Agrobiological, University of Tokyo, Tokyo 113, Japan.

Nematocera evolved from a stock preadapted for blood sucking. Later, Culicidae and Chironomidae which mate in swarm with the plumose antennae were separated from Tipulidae and Psychodidae in the Triassic area. In Culicidae, Toxorhynchitini, Sabethini and many other autogenous species in other tribes are considered to have lost secondarily their blood feeding habit. They are sedentary and need not to swarm for mating. The facultative and delayed autogeny traits in many other anautogenous species also suggest that speciation may further occur based on these traits. On the contrary, the species dispersing for blood sources are ensured for high reproductive and gene flow. Most males of *Anopheles*, *Ochlerotarsus* of *Aedes*, *Psorophora* and *Culex* travel long distance and wait at areas where receptive females are numerous. They swarm there to mate. Swarming near a breeding site may be primitive, but swarming at a resting or host site may be evolutionarily developed. Reproductive isolation mechanisms of colonized or sibling species have been observed in the assortative mating of released males, in swarmings at different sites, heights and times of day, by stenogamous males and on different frequencies of female wingbeat sounds.

EVOLUTION OF TREE-HOLE MOSQUITO COMMUNITIES: COEVOLUTION OR ADAPTIVE OPPORTUNISM? W. E. Bradshaw* and C. M. Holzapfel, Department of Biology, University of Oregon, Eugene, OR 97403, USA.

Examination of tree-hole mosquito communities in both North America and western Europe reveals dramatic macro- and micro-habitat partitioning among the constituent species. This segregation is sufficient to explain the continued coexistence of all species in their respective communities. Open niches still exist and, in at least one case, are in the ongoing process of being exploited. The determinants of habitat segregation are generally genus-, most species-specific characters. Congeneric habitat segregation does occur among two sympatric pairs of sibling species but at least one of these pairs probably differentiated allopatrically. Thus, the pattern of habitat segregation among North American and European tree-hole mosquitoes has more likely evolved through a process of adaptive opportunism and competitive exclusion than through a process of co-evolved niche shifts.

THE EVOLUTION OF OSMOREGULATORY ABILITIES IN MOSQUITOES. T.J. Bradley. Dept. of Develop. and Cell Biol., Univ. of Calif., Irvine, USA. 92717

Mosquitoes arose and developed much of their present phylogenetic diversity as insects with obligate freshwater larvae. Ca. 95% of all extant mosquito species possess larvae which are restricted to fresh water because they can produce a very dilute urine but not a concentrated one. Mosquitoes in at least 9 genera have evolved larval osmoregulatory mechanisms which allow survival in hypersaline media. In the genera *Aedes*, *Opifex* and *Anopheles*, the larvae in some species are capable of osmoregulation in saline waters due to the capacity to secrete a hyperosmotic urine. By contrast, larvae of some species of *Culex*, *Deinocerites* and *Culiseta* survive in saline media by allowing the hemolymph to osmoconform through the accumulation of organic solutes in the hemolymph. A strategy of osmoregulation arose independently at least three times in mosquitoes while osmoconformation arose independently at least twice. The evolutionary pathways by which saline tolerance arose repeatedly in mosquitoes can be deduced using phylogenetic and physiological techniques. (Supported by NSF grant DCB 8608664).

ETHOLOGICAL ISOLATION AMONG SPECIES OF THE SOUTH PACIFIC *AEDES SCUTELLARIS* GROUP. D.K. McLain, Biology Department, Georgia Southern College, Statesboro, Georgia 30460, USA.

Laboratory ethological isolation tests were performed by placing the females of one species in a mating arena containing an excess of both males of their own and another species. Mating pairs were aspirated from the test chamber and the species of male identified by examination of terminalia. An isolation index $[(\text{no. homogamic} - \text{no. heterogamic matings}) / \text{total no. matings}]$ and its standard error were calculated for each species pair. For eight species in the *Aedes scutellaris* subgroup the degree of isolation was correlated with geographic separation along the outer Melanesian arc. For species pairs along the arc, the species with a more eastern geographic distribution exhibited greater mate discrimination suggesting evolution along the arc from east to west. For species within the *A. albopictus* subgroup, ethological isolation was significant between pairs of species only if the populations tested were sympatric. This suggests reinforcement for ethological isolation in sympatry and also that the species in the subgroup are relatively young since divergence has not occurred in allopatry.

BIOGEOGRAPHY OF MONTANE CARABIDAE IN NORTH AMERICA WITH COMPARATIVE NOTES ON THE FAUNAS OF THE ROCKY AND ANDEAN MOUNTAIN SYSTEMS. G.R. Noonan, Invertebrate Zoology Section, Milwaukee Public Museum, Milwaukee, WI 53233.

Analysis of the biogeography of members of the genus *Harpalus* shows that portions of the Rocky Mountains and Sierra Nevadas were refuges into which grassland adapted species retreated during past periods of dryer climates. During isolation in such refuges the populations diverged in morphological characters; periodic isolation in the montane refuges resulted in the production of new forms which later invaded grasslands during periods of moister climates. Preliminary sampling of various Carabidae in the Andes and Rocky Mountains suggests that the Andean grassland fauna is impoverished relative to that of the Rocky Mountains. Disparities in these faunas relate to differences in climates and habitats of surrounding lowlands and to differences in climates, habitats and moisture sources within the mountains.

BIOGEOGRAPHY OF MONTANE REFUGIA IN NORTHERN AUSTRALIA. M. BAEHR, ZOOLOGISCHE STAATSSAMMLUNG MÜNCHEN, MÜNCHHAUSENSTR. 21, 8000 MÜNCHEN 60, F.R.G.

Species of hygrophilous Carabidae condense in the montane refugia of Arnhem Land, Kimberley Division, and Hamersley Range where the fauna is at least as diverse as in comparable areas of North Queensland. Generally, the species of the northern refugia are phylogenetically more advanced, than those of North Queensland. Hence the species of the northern refugia are mainly derived from more generalized ancestors, much like those species still living in North Queensland. Speciation proceeded by range spreading in a westerly direction over most of northern Australia during wet Glacials and subsequent isolation in the wetter refugia during dry Interglacials. Several successions of range spreading and isolation account for the repeated invasion of related species into the northern refugia and result in the presence of several related species of different evolutionary status there. The low species diversity in North Queensland depends on the comparatively wet conditions in the past which prevented the evolution of new species.

TESTING TAXON CYCLE SCENARIOS USING BIOGEOGRAPHIC PATTERNS OF MONTANE MEXICAN AND ANTILLEAN CARABIDAE. J.K. Liebherr* and Ann E. Hajek, Department of Entomology, Comstock Hall, Cornell University, Ithaca, New York, U.S.A. 14853-0999.

The assumptions of the taxon cycle (Wilson 1961) and taxon pulse (Erwin 1985) are reviewed, and their predictions recast in a cladistic framework. When considered as cladistic scenarios, both predict: 1) sister groups will not differ greatly in their ground-plan habitat preference; 2) of two sister groups, the one inhabiting the more ecologically unstable habitat will be less speciose; 3) cladistically more apical taxa on a cladogram will occur in more geographically restricted, and more ecologically specialized habitats; 4) habitat specialization is irreversible. These predictions are tested against empirical patterns of altitudinal and geographic range distributions in Mexican and Antillean platynine and pterostichine Carabidae. The empirical data surveyed do not differ significantly from randomly generated distributions.

RELATIONSHIPS BETWEEN ISLANDIC AND MAINLAND GROUND BEETLE (COLEOPTERA: CARABIDAE) FAUNAS OF THE PACIFIC COAST OF NORTH AMERICA. D.H. Kavanaugh, Department of Entomology, California Academy of Sciences, San Francisco, California, USA 94118.

Analyses of carabid beetle faunas of islands along the Pacific Coast of North America generally indicate close affinity with and recent derivation from faunas of adjacent mainland areas. Islandic endemism is low and restricted to three areas: the Aleutian Islands, the Queen Charlotte Islands, and Guadalupe Island. Comparisons of geographical ranges of species represented on islands from Vancouver Island and Puget Sound northward reveal that six faunal elements are represented: (1) Holarctic, (2) Transamerican, (3) Western North American, (4) West Coastal, (5) Local Endemic, and (6) Introduced European elements, with elements (3) and (4) contributing about two-thirds of the species present. In contrast, only two elements, (1) Southwest Coastal and (2) Local Endemic elements, are represented on southern islands. Faunal diversity is compared among islands and between islands and the mainland in relation to habitat. Geologic and biotic histories of the islands, origins of their extant carabid faunas, and the effects of Pleistocene events on these faunas are also discussed.

A BIOGEOGRAPHICAL ANALYSIS OF THE DISTRIBUTION OF CARABID GENERA IN S.E. ASIA. N.E. Stork, W. van Meerendonk* and J. Krikken. Dept. of Entomology, British Museum (Natural History), Cromwell Rd. London SW7 5BD, U.K. and *Coleoptera Section, Rijksmuseum van Natuurlijke Historie, P.O. Box 9517, Leiden, The Netherlands.

The distribution of carabid and cicindelid beetle genera throughout the S.E. Asian archipelago, as assessed from the current literature and from study of major recent collections, is analysed to establish the faunal relations of the main geographical units of this area. Comparisons are made with the results of similar published studies on other groups of animals.

DIFFERENCES IN THE TRECHINE FAUNAS OF THE PHILIPPINES AND TAIWAN. Shun-Ichi Uéno, Department of Zoology, National Science Museum (Nat. Hist.), 3-23-1 Hyakunin-chô, Shinjuku, Tokyo, 160 Japan.

Though lying side by side to the east of the Asiatic Continent, the Philippines and Taiwan are considerably different in the composition of the carabid faunas. In the former, trechines in a strict sense are found only on the high mountains of Luzon, where eleven species belonging to the two genera, *Trechus* and *Luzonotrechus*, have been known. In the latter, eight species distributed to four different genera have hitherto been found, that is, one species each of *Trechiana*, *Agonotrechus* and *Taiwanotrechus*, and five species of *Epaphiopsis*. Both the faunas must have originated in southern China, but the eastward dispersals of their ancestors seem to have taken place independent of each other. The trechine fauna of Taiwan, whose high mountains attain to an elevation of nearly 4,000 m, is more diverse than that of the Philippines, and has closer affinity to those of the Asiatic Continent and Japan. The trechine fauna of the Philippines, on the other hand, is much isolated, and seems to have been derived from only two ancestors that reached Luzon across the South China Sea by sweepstakes dispersal.

INFLUENCES OF ECOLOGICAL ISLANDS ON THE BIOGEOGRAPHY OF THE GENUS CICINDELA IN THE INDIAN-SUBCONTINENT (COLEOPTERA).
D.L. Pearson*, Department of Biology, 208 Mueller, Pennsylvania State University, University Park, Pennsylvania USA 16802, and K. Ghorpade, P. O. Box 2564, Bangalore, India 560 025.

The Indian Sub-continent has the most diverse tiger beetle fauna in the world. A combination of dispersal and vicariant events together with biotic and abiotic ecological factors are used to interpret present day patterns of distribution and diversity. Within the single genus Cicindela (sensu latu), 146 species occur, and all but 29 species in the subgenus Jansenia are relatively recent arrivals from China-Malaya (40%), Palaearctic (32%) or Africa (9%). Endemism and unique ecological and habitat specialization are associated with the long term presence of species of Jansenia as well with small, more genetically labile species in recently arrived subgenera. Previously described theories of biogeography of plants, fish, birds and butterflies on the Indian Sub-continent are compared to those for tiger beetles, and they reveal many shared patterns.

TAXONOMIC CHALLENGE IN THE BIODIVERSITY CRISIS: INTRODUCTORY REMARKS. M. Kosztarab, Department of Entomology, Virginia Polytechnic Institute & State University, Blacksburg, Virginia 24061, USA.

To preserve endangered species and habitats, a new collecting philosophy is needed. Emphasis should be on selective rather than mass collecting methods. Specific recommendations include: restricting collecting in certain habitats; establishing "island" reserves; reducing population sample size to a minimum; utilizing "strip collecting methods"; and using more species-specific trapping methods, such as pheromone traps. Unneeded trapped specimens, their parasites, and predators, should be released into the original habitats.

Computerized data banks should be established on the already available population samples in various collections to avoid useless duplication of material. Other urgent needs include: the training of a new generation of taxonomists, especially in the developing countries, with ingrained conservation ethics; also establishing a center and initiating yearly conferences on biodiversity to coordinate needed worldwide efforts during the crisis.

THE BIOLOGICAL DIVERSITY CRISIS. Thomas E. Lovejoy, Assistant Secretary for External Affairs, A & I 1465, Smithsonian Institution, Washington, DC 20560, USA.

Although biological diversity is poorly explored and estimates of extinction rates are consequently imprecise, there is pretty wide consensus that extinction rates are soaring and that there is in fact a Biodiversity Crisis. In largest part this is because of high deforestation rates in the tropics, but habitat destruction is a major problem in most areas of the globe. This is compounded by pollution, regional problems such as acid rain, and global climatic change (e.g. greenhouse effect). The consequences of this biotic impoverishment for science and society will be discussed.

WHY BOTHER WITH ARTHROPODS IN THE BIODIVERSITY CRISIS? Daniel H. Janzen, Department of Biology, University of Pennsylvania, Philadelphia, Pennsylvania 19104, USA.

Conserved wildlands have two major classes of functions – economic and intellectual. Insects and insect biodiversity are major components of both. Insect economic value is particularly conspicuous in tropical wildland ecosystems, where insects are the primary pollinators of plants, the primary consumers of living plants and detoxifiers of the secondary compounds in those plants, the primary food of vertebrates and vertebrate prey, the primary reservoirs of parasitoids and arthropod carnivores. In short, insects are the primary glue in community structure, and the species are largely not interchangeable. However, the examples to be discussed are only the tip of the iceberg. Management of insects for their characteristics is in its infancy; the recent advances in biological control with insects realizes only a tiny fraction of insect potential. Insect intellectual value is even more conspicuous and even more unappreciated than is economic value. The human brain requires complex stimulation for its development, and the boring agroecosystem into which we are leveling the world is leading rapidly to biocultural deprivation. Conserved wildlands partly mitigate the effect. However, lions can be as boring as alfalfa. Plants in conserved wildlands are very diverse, but require a chemical eye to appreciate; they chew with their mouths closed. This leaves us with the insects in a conserved wildland as the true champions of diverse potential for intellectual stimulation to the ecotourist, the researcher and the schoolchild. And in the end, it is this stimulation for which tropical conserved wildlands will be truly valued.

INSECTS, THE OVERWHELMING BASIS OF BIODIVERSITY: WHY AND WHAT OF THE FUTURE. M.H. Robinson, National Zoological Park, Smithsonian Institution, Washington, D. C. 20008 U.S.A.

The author will examine the present state of knowledge about the extent of insect diversity and in particular the results of studies of the canopy of tropical rainforests. Causal explanation of this and other examples of insect diversity will be assessed in the light of general species diversity theory and the particular case of the canopy situation. Finally, an assessment will be made of the present situation vis-a-vis the destruction of rainforests and what can be done with *in situ* and *ex situ* methods of species rescue.

DIVERSITY AND DISTRIBUTION PATTERNS OF MITES

V.M. Behan-Pelletier, E.E. Lindquist and I.M. Smith*

Biosystematics Research Centre, Agriculture Canada, Ottawa, Canada K1A 0C6.

Among terrestrial and freshwater invertebrates, Acari are second only to insects in terms of number of species, and rival insects in terms of diversity of living habits and habitats occupied. The antiquity of mites, as evidenced by the recent finding of fossils from the Middle Devonian, 380m.y.a., for example, indicates that mites were already a diverse group when early terrestrial floras were developing. As with many groups of invertebrates, the diversity of mites is well documented for the Palaeoarctic, and to a lesser extent for the Nearctic and Australasian regions. The absence of data on diversity for most groups of mites in the tropics and subtropics is critical, because of the speed of alteration and destruction of habitats in these areas. Lack of these data limit our knowledge of the distribution patterns of mites and subsequently, interpretation of their origin, evolution and biogeography. Using examples from the major orders of mites, we will outline the extent of knowledge of acarine diversity worldwide. Where the distribution patterns of taxa have been established, we will show how this knowledge can effect our understanding of the historical and ecological processes that have influenced acarine evolution and shaped the composition and dynamics of modern communities.

TAXONOMIC RESOURCES IN ENTOMOLOGY. R.J. McGinley (USA) & L. Masner (Canada).

No Abstract

BIOSYSTEMATIC SERVICES IN ENTOMOLOGY AND THE BIODIVERSITY CRISIS. I.M. Smith, Biosystematics Research Centre, Agriculture Canada, Ottawa, Ontario, Canada K1A 0C6.

Existing biosystematic services have been organized to provide clients with names and other information for organisms implicated in various applied studies. Currently, demand exceeds supply capability. Services have been increasingly focussed on supporting research of special economic or social importance to the sponsoring government or funding agency. The recent world-wide trend to channel support for systematics in pursuit of limited and often short-term objectives is linked to political and economic approaches that remain popular. Consequently, established systematics organizations are ill-prepared to respond to the biodiversity crisis. Even in some seemingly developed countries the arthropod fauna remains poorly known and biological survey initiatives are inadequately supported. New resources and mechanisms are required to provide the kind and scope of biosystematic services needed to document and assess arthropod diversity. The needs can best be met through a broadly-based international agency able to commit long-term support for developing and maintaining an automated, interactive records network as the basis for a global biological information system.

BIOSYSTEMATICS AS A FOUNDATION OF RESEARCH IN THE FIELD OF THEORETICAL AND APPLIED ENTOMOLOGY. V.F.Zaitzev, Zoological Institute Academy of Sciences, Leningrad, USSR, 199034.

Reability and significance of all scientific investigations in the field of entomology and a successful solution of the practical programs based on them undoubtedly depend on precision of species diagnoses of insects. However diagnostics is only one of the aspects biosystematics. The main application of biosystematics as a separate biological discipline is provided by its classification, explanatory and prognostication potentialities. However we have to state that "systematics" as a speciality is losing its prestige and is becoming rare. At present even large countries with highly developed economy cannot afford for systematics in all groups of insects. International cooperation in insect biosystematics is required. One of the ways of such cooperation is using computers in taxonomy and development of a single and common zoological data bank.

HUMAN RESOURCES IN INSECT SYSTEMATICS. L. Knutson (USA).

No Abstract

HOW ARE WE GOING TO MEET THE CHALLENGE? CLOSING REMARKS. K.C. Kim (USA).

No Abstract

EMBRYOGENESIS OF EVERSIABLE SAC AND PLEUROPEDIA OF GALLOISIANA NIPPONENSIS (CAUDELL ET KING). H. Ando, Sugadaira Montane Res. Cen., Univ. Tsukuba, Sanada, Nagano, Japan.

Notopteran insects have a strange organ, eversible sac on the sternum of the first abdominal segment often thought to show their primitiveness, because the similar organs paired are found usually in the abdominal segments of apterygotans.

The embryonic development of the eversible sac and pleuropodia also appeared in the first abdominal segment, of *G. nipponensis* was studied and following results obtained.

1) Eversible sac : The rudiment of a sac begins to develop in the middle of the embryogenesis and the sac becomes to function at the hatching. It is formed at the centroposterior end of the sternum, and composed of the apical glandular and basal flattened wide parts.

2) Pleuropodia : Paired rudiments of pleuropodia develop in the prerevolution stage of embryo and degenerate at the hatching. The rudiments are formed at the both sides of the first abdominal ganglion, and belong to the invaginated type of pleuropodia. The pleuropodia secrete the evaginated part at about katabolism of the embryo.

It will be considered that the relation of the both organs and the nature of the eversible sac.

GRYLLOBLATTIDAE IN THE JAPANESE ISLANDS: TAXONOMY, DISTRIBUTION AND ECOLOGY. T. Yamasaki, Department of Natural History, Faculty of Science, Tokyo Metropolitan University, Fukazawa, Setagaya, Tokyo 158, Japan.

Six species of Galloisiana have hitherto been described from the Japanese Islands, but there are some more species awaiting descriptions. These undescribed species will be outlined and some information on their distribution and ecology will be given. Discussion on the generic and subgeneric taxonomy will also be made.

NOTES ON NORTH AMERICAN GRYLLOBLATTIDS. V.R. Vickery* and D.K.McE. Kevan, Department of Entomology, Macdonald College of McGill University, Ste-Anne de Bellevue, PQ, H9X 1C0.

The knowledge and literature on North American species of *Grylloblatta* will be updated, including notes on biology of the "Kamloops" population.

TAXONOMY AND ZOOGEOGRAPHY OF GRYLLOBLATTA (NOTOPTERA: GRYLLOBLATTIDAE) IN WASHINGTON, U.S.A. R.L. Crawford and J.S. Edwards*, Burke Memorial Museum and Department of Zoology, University of Washington, Seattle, WA 98195, U.S.A.; C.M. Senger, Department of Biology, Western Washington University, Bellingham, WA 98226.

At least 10 tentatively identified *Grylloblatta* spp. occur in the Cascade Mountains and foothills of Washington. *G. occidentalis* Silvestri and *G. scudderii* Kamp, sympatric near Mt. Baker, are subalpine-alpine snowfield foragers, as is an undescribed species reported from Glacier Peak to the south. A fourth such species occurs in the central and southern Cascades, notably on Mt. Rainier, at elevations of 1520-2440 m. A forest species occurs from Mt. Baker south to Mt. Rainier in surface locations and limestone caves from 305-1520 m; a second lowland species is found north of Mt. St. Helens and survived the recent volcanism there. Two partly sympatric cave species, *G. chirurgica* Gurney and one undescribed, occur in the 1900 year old Cave Basalt lava flow south of Mt. St. Helens; a third and possible fourth cave species occur in older lava flows to the east. Contrary to reports of Oregon cave *Grylloblatta*, these species are not restricted to caves containing ice and do not migrate seasonally to the surface. Frequent sympatry indicates that *Grylloblatta* evolution in the Cascades has been more complex than previously thought.

GRYLLOBLATTIDS OF MOUNT ST. HELENS. J.S. Edwards* and P.M. Sugg, Department of Zoology, University of Washington, Seattle, WA 98195

The explosive eruption of Mount St. Helens on May 18 1980 devastated an area of about 600 sq km, of which about 100 sq km retained no vestige of its former biota. In the remainder of the area there persisted residual populations of resident species surviving in refugia of various sorts.

The pre-eruption grylloblattid fauna of the devastated zone of Mount St. Helens is unknown, but one species *Grylloblatta chirurgica* was known from lava tube caves on the mountain. This area was subjected to heavy tephra fallout but *G. chirurgica* survived the eruption (R.L. Crawford, pers. comm.). A population of grylloblattids also survived heavy tephra fallout in boulder talus on the southeast flank of the volcano. This appears to be an undescribed species. Grylloblattids have also been found at a number of sites in the devastated area indicating that the pre-eruption populations were generally distributed; lack of mature individuals prohibits assignment of these to a species.

THE ORIGIN AND DISTRIBUTION OF MARINE WATERSTRIDERS (HEMPTERA, GERROMORPHA). N. Møller Andersen, Zoological Museum, University of Copenhagen, Universitetsparken 15, DK-2100 Copenhagen, Denmark.

About 100 species of gerromorphan bugs, representing four families and six subfamilies, inhabit the marine environment, chiefly the nearshore areas of tropical seas with a strong tidal influence. It is estimated that the marine habitats have been colonized (from freshwater habitats) once or twice during the evolution of the Mesovelidae, four times in the Veliidae, and four times or more in the Gerridae. The family Hermatobatidae contains only marine species.

The majority of marine waterstriders occur in the Indo-Pacific area, along the continents and islands bordering the Red Sea, the Indian Ocean, and the western Pacific Ocean, as well as on oceanic islands and island groups in these areas. The veliid genera *Halovelgia* and *Xenobates* have radiated extensively in habitats of intertidal coral, rocky, and mangrove coasts, especially in the Indo-Malayan, Papuan, and Australian subregions. The ocean skaters *Halobates* show an almost similar distribution. Five species have colonized the open ocean and have dispersed into all tropical areas of the Atlantic, Indian, and Pacific oceans. The phylogeny and biogeography of marine waterstriders are discussed.

THE BIOLOGY OF INTERTIDAL GERROMORPHA.

W.A. Foster, Department of Zoology, University of Cambridge, Cambridge, CB2 3EJ, U.K.

Within the semi-aquatic bugs, there have been several independent invasions of the intertidal zone, and one genus, *Halobates*, has gone on to colonize the open ocean. Relatively little is known about the adaptations of these genera to intertidal life. I will discuss recent field observations on three genera from the coasts of tropical Pacific islands. *Hermatobates* and *Halovelgia* live in air pockets under stones and emerge at low tide to feed and copulate on the surface of the sea. *Halobates* lives permanently on the sea surface, but the coastal species lay their eggs within the intertidal zone. The morphological, behavioural and ecological adaptations of these genera to life in the intertidal zone will be discussed.

WITHIN-HABITAT DIVERSITY OF THE GERRIDAE OF SULAWESI.

Diane M. Calabrese, The Bunting Institute, 34 Concord Avenue, Cambridge, Massachusetts 02138, USA.

Possible explanations of the very high number of gerrid genera represented in the Indo-Austral Region can be summarized: 1) the pattern is an artifact (i.e. the fauna of other regions is less well known); 2) there are more habitats available for gerrids; 3) within-habitat diversity of gerrids is high. Data derived from fieldwork in northeast Sulawesi provide corroboration for the hypothesis that within-habitat diversity is high. Moreover, the results of analyses of size relationships among sympatric gerrid species reveal at least one mechanism - reduced competition for prey - which contributes to the maintenance of the pattern of high within-habitat diversity.

ZOOGEOGRAPHY OF THE GENUS *RHAGOVELIA* IN THE MALAY ARCHIPELAGO (HEMPTERA: VELIIDAE). J. T. Polhemus and D. A. Polhemus, Univ. of Colorado Museum, 3115 S. York St. Englewood, Colorado, USA 80110

The genus *Rhagovelgia* is widely distributed in the Southern Hemisphere, primarily in the tropics, but is absent in Europe and has succeeded in only limited penetration of North America and Asia, indicating it originally had a Gondwana distribution. In the Malay Archipelago the genus has few species on Java, Sumatra, and the volcanic Banda Arc, but has undergone a secondary radiation in Borneo, Celebes, New Guinea and the Moluccas. Our research indicates that the fauna of the eastern archipelago is derived from three source areas: southeast Asia, Australia, and New Caledonia. Distinct lineages appear to have entered the region from each of these areas, contributing to the faunas of individual islands to differing extents. Species groups of continental Asian origin do not extend eastward of Celebes and the Lesser Sundas, species of Australian origin are absent in the Lesser Sundas and do not extend west of Borneo, and species of New Caledonian origin do not range beyond New Guinea. Endemic species groups have arisen in Borneo, New Guinea, the Philippines and the northern Moluccas, primarily in response to episodes of mountain uplift which have produced isolated islands of montane habitat.

EFFECTS OF PLEISTOCENE GLACIATION ON THE DISTRIBUTION OF WATER STRIDERS (HEMPTERA: GERRIDAE) IN THE EASTERN UNITED STATES. Paul D. Kittle, Department of Biology, University of North Alabama, Florence, Alabama, U.S.A. 35632.

The effects of Pleistocene glaciation on the evolution and distribution of the sister species *Rheumatobates palosi* and *R. rileyi*, the sister species *Trepobates inermis* and *T. knighti*, and the geographic races of *T. subnitidus* will be discussed.

PRELIMINARY RESULTS OF REARING EXPERIMENTS WITH *MICROVELIA* (HEMPTERA: VELIIDAE). Nico Nieser, Htg. Edwardstraat 16, 4001 RG Tiel, The Netherlands.

Rearing experiments of *Microvelia reticulata* (Burm.) led to strong indication of, at least partly, density dependent regulation of macropterism. Results in *M. umbricola* Wrobl. were not conclusive.

ABUNDANCE AND CO-OCCURRENCE OF *GERRIS COMATUS* AND *GERRIS ALACRIS* IN RELATION TO PARASITISM BY LARVAL *LIMNOCHARAS AQUATICA*. B.P. Smith, Department of Biology, University of New Brunswick, Fredericton, New Brunswick, Canada E3B 6E1.

Gerris comatus is preferred 7-fold over *G. alacris* by *L. aquatica* mites. Average loads of 35 mites and prevalence of 100% are common among adult *G. comatus* in natural populations during midsummer. In laboratory studies, natural levels of mite infestation for *G. comatus* resulted in severe mortality among first instar water striders.

Co-occurrence of these two gerrid species is apparently mediated by mite parasitism. Overwintered *G. comatus* and *G. alacris* co-occur in shoreline habitats, producing their first generation. *Gerris comatus* disappear from shorelines in mid-June, coinciding with intense parasitism. Populations of the two gerrids are spatially separated during their second and partial third generations, with *G. comatus* inhabiting offshore habitats beds of water millfoil.

PARASITISM OF WATERSTRIDER EGGS BY A SCELIONID WASP IN FINLAND - PRELIMINARY RESULTS. K. Vepsäläinen, Department of Zoology, University of Helsinki, P. Rautatiekatu 13, 00100 Helsinki, Finland.

The wasp *Tiphodytes gerriphagus* is known to be an intensive parasitoid on waterstrider eggs in Canada. Lately the same species has been reared from field-collected eggs of Finnish striders. According to the first-summer results the rate of parasitism varied between 0 and 83% among the sites and/or species.

I shall speculate on the relations among the oviposition patterns, the rates of parasitism, the life-histories, interspecific competition and habitat structures in different waterstrider species.

A COMPARATIVE STUDY ON LIFE HISTORY TRAITS OF THREE WING-DIMORPHIC MICROVELIA SPECIES (HEMIPTERA: VELIIDAE). M. Muraji*, F. Nakasugi, Faculty of Agriculture, Okayama University, Tsushima, Okayama, 700 Japan.

Life history traits of three veliid water striders, *Microvelia horvathi* (MH), *M. douglasi* (MD), *M. kyushuensis* (MK), were studied in relation to the wing-dimorphism and the habitat utilization.

The frequency of winged forms of all species increased with increase of the nymphal density. The sensitivity to the density was higher in MH and MD than MK. The developmental period of immature stages of MK was longer than MH and MD at all temperatures of 20, 24, 28 and 32°C. The period of MD was longer than MH at 20 and 32°C. The susceptibility of eggs to desiccation was highest in MK, and 100% death occurred within 24 hr at 65% RH 25 °C. Both morphs of MK had a longer preoviposition period, less fecundity and lower reproductive potentials (R_0 and r_m) than MH and MD. The fertility of apterous form was higher than macropterous form for all species. The difference between the two forms was largest in MH especially early stages of females. The fertility schedule, m_x curves, of MK was rather flat throughout the life span, although the curves of MH and MD had a peak in early stages. All of the traits suggested that MH and MD adapted to the unstable habitat and MK adapted to the stable habitat. Field observations supported this prediction.

POPULATION STRUCTURE AND LIFE CYCLE OF MICROVELIA AND MESOVELIA SPECIES (HEMIPTERA: VELIIDAE, MESOVELIIDAE). M. Zimmermann, Zoological Institute, University of Berne, Baltzerstrasse 3, CH-3012 Berne/Switzerland.

Four species (*Microvelia reticulata* and *M. buenoi* (Velidae); *Mesovelia furcata* and *M. mulsanti* (Mesovelidae)) were studied in the field and in the laboratory. Regular samples taken over at least one season indicate that in Central Alberta *M. buenoi* is univoltine, and *M. mulsanti* partially bivoltine; on the Swiss plateau *M. reticulata* is bivoltine and *M. furcata* trivoltine. All four species are wing-polymorphic, and except for *M. mulsanti* the LW-morph is rare throughout the year. In *M. furcata* the proportion of LW-adults showed a strong positive correlation with rearing density.

SEXUAL SELECTION IN A WATER STRIDER: THE FUNCTION, NATURE OF SELECTION AND HERITABILITY OF A MALE GRASPING APPARATUS. G. Arnqvist, Dept. of Animal Ecology, S-901 87 Umeå, Sweden.

The water strider *Gerris odontogaster* (Zett.) (Heteroptera: Gerridae) exhibits sexual dimorphism regarding a male grasping apparatus, consisting of two abdominal ventral processes. The processes provide males with a posterior attachment during mating. Females were reluctant to mate, and the abdominal processes were essential for males to succeed with forced copulations. Behavioural observations, showing low male mating success and absence of take-overs, suggested intersexual selection as the major agency in the evolution of the processes.

Comparisons of the mating and non-mating fractions of a natural population showed significant ($p < 0.001$) difference in length of male abdominal processes, thus indicating sexual selection to operate in the field. The heritability for length of processes was estimated from parent-offspring regression. The heritability of process length was found to be high ($h^2 = 0.70$) in opposite to what is predicted by quantitative genetic theory, since length of processes is likely to be an important male fitness component. The maintenance of additive genetic variation is discussed, and the results are interpreted as an illustration that, although overall fitness may have negligible additive genetic variance, different components of fitness may exhibit considerable heritable genetic variation.

A COMPARATIVE STUDY OF THE MATING SYSTEM OF GERRIS IN JAPAN. K. Hayashi, Department of Biology Faculty of Science Kyushu University Fukuoka 812 Japan

Twenty-one species of water striders are known from Japan and six species of *Gerris* are found in Fukuoka; *Gerris esakii*, *G. paludum*, *G. elongatus*, *G. gracilicornis*, *G. lacustris* and *G. amenbo*. Larger species of *G. elongatus*, *G. paludum* and *G. gracilicornis* are usually found on open water and smaller species of *G. esakii*, *G. lacustris* and *G. amenbo* are found on the vegetation or floating leaves. I observed the mating behavior of 5 species and found that there were two types of male mating system in *Gerris*. One is territorial male mating system and found in *G. elongatus*. Territorial males were large, while nonterritorial males were small and had few chances to copulate, suggesting a system of resource defence polygyny. In other *Gerris*, males, moving on the surface to search females, were nonterritorial. Most mature males usually rode on female's back, guarding from other males for long time, suggesting scramble competition polygyny. But, the duration of guarding time varied among species. These differences in male mating behavior may correlate with the environmental differences of their habitats. The ecological factors affecting inter-specific diversity in male mating system are discussed.

MATING BEHAVIOR OF GERRIS NAJAS (HEMIPTERA: GERRIDAE) IN THE LABORATORY UNDER DIFFERENT PHOTOPERIODS. R. Köpfli and R. Hauser, Zoological Institute, University of Berne, Baltzerstrasse 3, CH-3012 Berne/Switzerland.

Adult *Gerris najas* from a wild population were kept under either long-day (stationary 18L:6D) or short-day conditions (stationary 10L:14D). *G. najas* shows mate guarding, the male remaining seated on the back of the female after copulation. This behavior allows to distinguish between reproductive and non-reproductive imagines. Regardless under which photoperiod the nymphs were reared, adults started to reproduce when kept in longday and stayed non-reproductive in shortday. After subsequent transfer into the alternative photoperiod adults changed their reproductive state within three weeks.

In our *G. najas* population reproduction/nonreproduction seems to be directly controlled by the photoperiod experienced by the adults, whereas in other *Gerris* species the photoperiodic conditions during a sensitive nymphal interval is decisive.

REPRODUCTIVE BIOLOGY OF *VELIA CAPRAI* TAM. (HEMIPTERA: VELIIDAE) IN SOUTHERN IRELAND. A.M. Murray and Dr. P.S. Giller, Department of Zoology, University College, Cork City, Ireland.

Velia caprai has long been considered univoltine, with adults overwintering in a reproductively immature state. The results of this study describe a more complex life-cycle. Earliest first instars were found in mid-March, two months earlier than any previous records. New generation adults were subsequently caught in mid-June. There is evidence to suggest that a second generation occurs under suitable conditions.

Populations studied during the Winter months were found to contain immature females, fully mature egg-bearing females, and a small proportion of fifth instar which did not moult until the following Spring. A proportion of the females showed ovarian maturation and egg deposition during the Winter months, while the remainder did not attain reproductive maturity until mid-Spring the following year. This ensures the species an earlier and longer instar production than the other inhabitants of the water surface. An ability to overwinter in any of the three different overwintering states also protects populations from being overly affected by adverse weather conditions during the late Summer and Autumn months.

BENEFITS OF COPULATORY GUARDING IN TWO SPECIES OF WATER STRIDERS. R. Stimson Wilcox and Penny Ashton, State University of New York, Binghamton Biology Department, SUNY-Binghamton, New York 13901, USA.

Mating pairs of the water strider species *Gerris remigis* and *G. conformis* remain continuously in copulo (*G. remigis*), or copulate intermittently but remain together as pairs continuously (*G. conformis*), for long periods, up to 1 day (*G. remigis*) or even more than 2 days (*G. conformis*). The energetic cost for females to carry males so long, and the potentially lowered fitness investment for males by thus limiting mating partners, is compensated in females by a greatly enhanced ability to forage, since copulating/clasping males guard against harassing mating takeover attempts by other males. Guarded *G. conformis* females also produce more eggs than unguarded females. Presumably males benefit by increased paternity assurance, owing to underwater oviposition in *G. remigis* and male-guarded oviposition in *G. conformis*.

COST OF FLIGHT ABILITY AND REGIONAL CHANGES IN REPRODUCTIVE TACTICS OF *GERRIS THORACICUS*. A.L. Kaitala, Univ. of Helsinki, Dept. of Zoology, P. Rautatiekatu 13, SF-00100 Helsinki 10, Finland.

The longwinged waterstrider *Gerris thoracicus* Schumm. has two morphs: "Flyers" are able to fly throughout reproductive period, while "non-flyers" lose their flight ability during reproduction. In Finland, at the northern border of the distribution of *G. thoracicus*, flyers were the dominant morph in unstable rock pools and non-flyers were the dominant morph in cool but stable sea habitats. In the laboratory non-flyers laid more eggs, when food was abundant. During food deprivation both of the morphs were able to extend their lifespan by switching off reproduction, but non-flyers survived better than flyers.

In Central Europe this species frequently coexists with other waterstriders in many habitats. Flyers were the most common morph in Hungary. In contrast to both of the Finnish morphs, Hungarian females did not show flexibility in reproductive behaviour in response to changes in food abundance. The roles of climate, habitat stability, competition and parasitism are discussed as an adaptive explanation for regional differences in reproductive tactics.

CORRELATED TRAITS FOR DISPERSAL TENDENCY IN THE GERRINAE. D.J. Fairbairn. Department of Biology, Concordia University, 1455 de Maisonneuve Blvd., Montreal, Canada H3G 1M8

Alary polymorphisms are common within the Gerrinae, and are widely presumed to reflect the strength of selection for dispersal ability. This paper tests the hypothesis that selection for dispersal ability affects not only the proportion of macropters within a population, but also the flight capacity of the macropterous morph. The flight capacities of four species are compared under both lab and field conditions. The species range from monomorphic macropterous (*Limnoporus dissortis*), through seasonally polymorphic (*Gerris conatus* and *G. buenoi*), to primarily apterous (*G. remigis*). Long term mark-and-recapture studies of field populations reveal significant positive associations between the proportion macropterous, the proportion of macropters that disperse by flight, and the proportion of macropters found in ephemeral habitats. Laboratory experiments demonstrate a significant negative association between the flight thresholds of adults with fully developed wing muscles and the proportion macropterous. The extent and timing of wing muscle histolysis is also shown to be negatively associated with the proportion macropterous. These data thus demonstrate that the flight capacity of macropters, as assessed by wing muscle development, flight threshold, and dispersal in the field, is positively associated with the proportion macropterous in these four species. The general hypothesis that selection for dispersal ability affects both flight capacity and proportion macropterous is thus supported.

DIAPAUSE INDUCTION AND WINGLENGTH DETERMINATION IN *GERRIS LACUSTRIS* (HEMIPTERA: GERROMORPHA). R. Hauser*, R. Köpfli and M. Zimmermann, Zoological Institute, University of CH-3012 Berne, Switzerland.

Analysis of natural populations and crossing experiments with inbred laboratory strains reveal that in *G. lacustris* the ability to respond to specific photoperiods with either reproductive diapause or nondiapause is genetically determined. Our experiments furthermore elucidate the respective importance of hereditary and environmental factors in the control of winglength in this pterygopolymorphic species.

DISPERSAL AND THE POPULATION DYNAMICS OF TWO CO-EXISTING POND SKATER SPECIES (GERRIDAE). J.R. Spence, Department of Entomology, University of Alberta, Edmonton, Alberta, Canada T6G 2E3

Populations of adult gerrids were studied on a small pond in central Alberta by total census and marking carried out weekly over a 4 year period. Five gerrid species occurred but only two species, *Limnoporus dissortis* and *Gerris buenoi*, accounted for >98% of recruitment. Overwintered breeding populations peaked in mid-late May and both species produced partial second generations in all years. All individuals of both species were macropterous except the summer breeding generation of *G. buenoi* which was partially short winged. Overwintered gerrids flew into the pond between April and late June and observed immigration rates account for the unmarked bugs captured each week. Marked emigrants were recovered on other ponds indicating that emigration also contributed to the 2-3 turnovers generally observed in spring breeding populations. Capture of flying females with fully developed eggs during most of the flight period shows that these species spread reproductive effort in space. Overwintered breeders remained on the pond for 4-6 weeks but variance in residence time was high. Bugs destined for diapause disappeared 2-3 weeks after the final molt and none were captured in pitfall traps with drift fences along the pond perimeter. Few marked adults reappeared on the pond in the subsequent year. The study shows that discrete populations of these species do not exist on the pond, even within seasons, and that flight is important during the reproductive period, and before and after diapause.

PHYLOGENY AND CLASSIFICATION OF EXOPORIA - AN OVERVIEW. E.S. Nielsen, Division of Entomology, CSIRO, GPO Box 1700, Canberra ACT 2601, Australia.

Exoporia are one of the most successful clades of non-ditrysian Lepidoptera and by far the most species-rich homoneurous group; they are morphologically diverse and occur worldwide. The monophyly of Exoporia is well supported as is the primary division into Mnesarchaeoidea and Hepialoidea. The current formal division of the latter into five families suffers from lack of support for the monophyly of the Palaeosetidae and the Hepialidae, the largest family, and the Hepialoidea is therefore better divided into 12 informal, but monophyletic entities. Four of these groups are removed from the Hepialidae of authors in order to make the Hepialidae s.str. monophyletic. Each of these 12 groups are briefly introduced and several characters useful in reconstructing their phylogeny are discussed but no phylogeny is proposed. The within-phylogeny of the Hepialidae is equally poorly understood but it is possible to discuss the primary divisions and define several monophyletic entities.

COMPARATIVE MORPHOLOGY OF EXOPORIA - AN OVERVIEW. N.P. Kristensen, Zoological Museum, University of Copenhagen DK-2100 Copenhagen Ø, Denmark.

Reconstructions of the exoporian ground plan are taking shape on the basis of forthcoming morphological observations on the Mnesarchaeoidea and some 'lower-grade' Hepialoidea. Although this ground plan is characterized by prominent autapomorphies, it is becoming evident that the ancestral exoporian moth was much less aberrant by 'generalized-glossatan' standards than are the best known 'typical hepialids'; this will be illustrated, e.g., by details in head structure, thoracic endoskeleton, and male genitalia. A tubular phallus is indeed present in male exoporian moths, but it is softwalled and closely appressed to the phallocrypt. The so-called 'tegumen' of hepialoids is reinterpreted as being a derivative of the lateroventral wall of segment X; thus it is not homologous with the tegumen (a dorsum IX formation) elsewhere in Lepidoptera. The ostium bursae of female Exoporia is interpreted as lying behind venter IX and its position is therefore non-identical with that of the Ditrysia. The hepialoid nerve cord is unexpectedly diverse.

EGGSHELL FINE STRUCTURE IN HEPIALID AND MNESARCHAEID MOTHS (LEPIDOPTERA: EXOPORIA) - EVALUATION OF ITS PHYLOGENETIC SIGNIFICANCE. H. Fehrenbach, Institut f. Biologie I (Zoologie) Albert Ludwigs Universität, Albertstr. 21 a D-7800 Freiburg, Fed. Rep. Germany.

A comparative electron microscopic study of the eggshell of hepialid and mnesarchaeid moths is presented. The species studied so far show a fundamentally identical fine structure of the vitelline envelope. The chorion, on the other hand, reveals differences: being homogeneously granular in the eggs of *Mnesarchaea* spp., it shows a crystalline-like fine structure in the hepialid eggs. However, chorion and vitelline envelope of both mnesarchaeid and hepialid moths are basically different from the ditrysian eggshell. The phylogenetic significance of the described character states of chorion and vitelline envelope are discussed on the basis of data on the eggshell fine structure of some non-neolepidopteran and monotrysian, heteroneuran species. The hypothesis is put forward that the Hepialidae and Mnesarchaeidae present a character state of the vitelline envelope which can be regarded as an autapomorphy of the Exoporia.

WING SCALE ULTRASTRUCTURE OF THE EXOPORIA (LEPIDOPTERA). D.L. Wagner*, Entomology Department, California Academy of Sciences, Golden Gate Park, San Francisco, California, USA, 94118, and E.S. Nielsen, Division of Entomology, GPO Box 1700, CSIRO, Canberra, ACT 2601, Australia.

The wing scales of the Exoporian Lepidoptera exhibit a broad range of ultrastructural complexity. The wing structure of each of the six Exoporian families was examined.

A variety of male scent scale types were found over the wing surfaces. These occurred either in glandular patches (e.g., *Phassodes* and *Palpifer*) or individually (e.g., *Trichopassus* and *Leto*).

Ultrastructural variation in the Hepialidae was studied in 67 species representing 39 genera. Individual, sexual, specific, generic, and suprageneric variation was demonstrated. Homologous scale types from the medial area of the forewing were studied in detail. Approximately 20% of the species and 30% of the genera could be accurately identified from an examination of the ultrastructure of these scales. In the clade containing *Hepialus*, *Sthenopsis*, *Aenetus*, and others, the secondary ridges were sometimes reduced or absent. No synapomorphic features for the family were identified.

SYSTEMATICS AND BIOLOGY OF MNESARCHAEIDAE (LEPIDOPTERA) G.W. Gibbs, Zoology Department, Victoria University, Private Bag, Wellington, New Zealand.

Mnesarchaea, the most diminutive of the exoporian Lepidoptera, is discussed from an evolutionary and biogeographical point-of-view. Fourteen species of these small forest moths are distributed throughout the two main islands of New Zealand. Their life history biology provides clues to their exoporian affinities. Morphological characters that link them to other Exoporia are discussed. The question of why they happen to be in New Zealand is not totally ignored.

THE PROTOHEORIDAE, AN INDIGENOUS FAMILY OF SOUTH AFRICAN MOTHS. Donald R. Davis, Department of Entomology, Stop 127, Smithsonian Institution, NMNH, Washington, D.C. 20560, USA.

The distribution, morphology, and systematics of the small South African hepialoid family Protoheoridae is reviewed. Among other features, development of an associated pair of copulatory structures in the male and female genitalia appear to characterize the family. The females possess a central, conjugal process arising ventrally from sternum IX. During copulation, this digitate process is believed to interlock with a corresponding conjugal pouch situated midventrally on the male trulleum. Two genera and six species are recognized, including one new species that was discovered in unusually xeric habitats.

REVIEW OF NEW ZEALAND HEPIALIDAE - CHIPS OFF OLD BLOCKS. J.S. Dugdale, Entomology Division, DSIR, Private Bag, Auckland, New Zealand.

Superfamily Hepialoidea in New Zealand is represented by 1 family, Hepialidae, with 3 isolated groups: *Aenetus* group (1 species); *Aoraia* group (13 species); "*Oxycanus*" group (5 genera, 15 species). Five genera include species with semiaquatic larvae in bogs, flushes or alpine cushion-bogs, associated with mosses (2 genera) or monocots. Three genera emerge as adults only in autumn or winter.

Aenetus and "*Oxycanus*" group genera are sister-groups of Australian taxa; relationships of *Aoraia* group are obscure. A re-definition of '*Oxycaninae*' based on female anogenital field structure is suggested.

THE ECOLOGY OF *WISEANA* IN NEW ZEALAND. N.D. Barlow, Ministry of Agriculture and Fisheries, PO Box 1654, Palmerston North, New Zealand.

Wiseana, referred to in New Zealand as porina, is the country's second most important pasture pest. Its ecology is dominated by interactions with virus and fungal diseases, intra-specific density-dependence and the effects of weather. Fungus disease has little effect on inter-generation population dynamics; and although viruses have the potential to regulate populations this is pre-empted by intra-specific density-dependence. Density-dependence arises from dispersal of moths and competition between surface-dwelling larvae. The key factor determining abundance in any one year is summer temperature, through its desiccating effect on surface larvae.

AN OVERVIEW OF HEPIALID BIOLOGY AND BEHAVIOR (LEPIDOPTERA). D.L. Wagner, Entomology Department, California Academy of Sciences, Golden Gate Park, San Francisco, California, USA, 94118.

The Hepialidae are the most fecund Lepidoptera, females may broadcast more than 45,000 eggs. Although the larvae are often local specialists, all are believed to be broadly polyphagous. Recorded diets include detritus, fungi, mosses, ferns, gymnosperms, and a variety of angiosperms. The cannibalistic larvae may even consume other soft-bodied arthropods. Most species are subterranean, a few are arboreal, and some occupy subaquatic environments. Larvae that tunnel in wood often exhibit a peculiar head-rattling behavior. Principal pathogens include entomophagous fungi, nematodes, and viruses; tachinids and ichneumonids are the most frequently reared parasitoids.

Most adults are crepuscular flying during a brief 20-30 minute window of twilight in the evening and again at dawn. Mating usually occurs during the vespertine flight; ovipositing females predominate during the matutinal flight. In most groups the female broadcasts the sex pheromone. In these the female mates before flying. In at least one clade, the calling system is reversed, with males producing the primary sex attractant. Here virginal females must fly to be mated. The putative male pheromones that have been identified are chemically unique.

THE BIOECOLOGY OF THE CONIFER SWIFT MOTH, *KORSCHTELLEUS GRACILIS* (LEPIDOPTERA: HEPIALIDAE). W.E. Wallner, Northeast Forest Experiment Station, 51 Mill Pond., Hamden, Connecticut, USA, 06514; B.L. Parker and D. Tobi, Entomology Research Laboratory, 655 Spear St., South Burlington, Vermont, USA, 05401.

Females lay up to 300+ eggs which hatch approximately two weeks later if held at room temperatures in saturated atmospheres. Emergence data for adults suggests that most larvae mature in two years. The larvae are among the most polyphagous Lepidoptera, consuming leaf litter, fungi, mosses, ferns, and the roots of conifers and various angiosperms. Pupation occurs in an elongate cocoon spun in the upper forest floor litter; adults emerge about one month later. Principal pathogens include three entomophagous fungi (*Beauveria*, *Entomophthora*, and *Hirsutiella*) and a diplogasterid nematode, *Mesodiplogaster*; parasitoids include the ichneumonid, *Pterocormus cresson* and the tachinids *Lixophaga unicolor* and a *Lydina* sp.

Local larval densities may exceed 40 larvae per 0.25 sq. m. in the high elevation red spruce-balsam fir forests of New England. Mean densities may exceed 10 larvae per 0.25 sq. m. or 160,000 larvae per acre. Virtually all spruce in these stands bear feeding wounds along their roots. The possible role of this insect in spruce decline in New England is discussed.

ANGIOSPERM AND FUNGAL FEEDING BY LARVAE OF *AENETUS VIRESCENS* (LEPIDOPTERA: HEPIALIDAE). J. R. Grehan, 47 Dover Road, Wainuiomata, New Zealand.

Early instars of *A. virescens* feed on dead, decaying wood or the fruiting bodies of woody basidiomycete fungi.

At approximately 2-3 months larvae transfer to live angiosperm trees or shrubs and feed on callus tissue induced by removal of bark. The diversity of feeding behaviour is described and the reciprocal constraints of organism/environment history on the evolution of feeding and larval development are discussed.

PHYLOGENY OF THE NEMATOCERA WITH REFERENCE TO SIMULIIDAE. D.M. Wood, Biosystematics Research Centre, Agriculture Canada, Ottawa, K1A 0C6.

Larvae of Dixidae and most Culicidae and Simuliidae feed in a complex and unique way on particles that they filter from surrounding water with their mouthparts. Contraction of a pair of massive muscles, the labral contractors, each inserted on the premandible, in turn attached to the torma, causes rapid, rhythmic closure of the labral brush. Particles entrapped by the setae of each brush, or adhering to its mucus coating, are collected in turn by the mandibular brushes and the epipharyngeal apparatus (midpalatal brush), and are ultimately pushed into the mouth by the prosthema or mandibular sweeper. So many complex structures and functions are shared by these larvae that a strong case must be made for homology.

Larvae of Ptychopteridae also filter algal particles from the water surrounding them, and ingest these particles in an essentially identical manner. Although feeding is much slower, the musculature smaller, and structure of the premandible and torma much less elaborate (hence apparently ancestral to the condition found in the above three families), mouthpart structure is apparently homologous. A sister group relationship between Ptychopteridae and the Culicomorpha is therefore proposed.

A PHYLOGENETIC INTERPRETATION OF THE PRIMARY EVOLUTIONARY LINEAGES OF SIMULIIDAE (DIPTERA: CULICOMORPHA). D. C. Currie, Department of Entomology, University of Alberta, Edmonton, Alberta, Canada T6G 2E3.

Analysis of all life-history stages of *Parasimulium* Malloch provides phylogenetic resolution of the earliest lineages of Simuliidae. Based primarily on features of the immature stages, a sister-group relationship is suggested between *Parasimulium* (=Parasimuliinae) and all other Simuliidae (=Simuliinae). Within Simuliinae, the initial dichotomy is as follows: Prosimuliini (*Prosimulium* Roubaud, *Helodon* Enderlein, *Urosimulium* Contini, *Parahelodon* Peterson, *Distosimulium* Peterson, *Levitinia* Chubareva & Petrova, *Twinnia* Stone & Jamnback, and *Gymnopais* Stone) and Simuliini (all other Simuliidae). The monophyly of each suprageneric lineage is discussed. The importance of considering all life-history stages in phylogenetic reconstruction is stressed.

Within Prosimuliini, a sister-group relationship is suggested between *Prosimulium* s.str. and all other genus-group taxa. The initial dichotomy within this latter lineage is between *Levitinia* + *Twinnia* + *Gymnopais* (the "fanless" black flies) and all remaining genus-groups (the "*Helodon* group"). This arrangement closely reflects published cytophylogenies, which are based solely on karyological information. A classification of Prosimuliini, which in many respects bridges the gap between the two most popularly followed schemes, is proposed.

A MOLECULAR STUDY OF SIBLING SPECIES RELATIONSHIPS IN THE SIMULIIDAE (DIPTERA). Charles Brockhouse* and N.A. Straus. Dept of Botany, University of Toronto, Toronto, Ontario, M5S 1A1, Canada.

Black flies (Simuliidae) are among the most thoroughly studied group of organisms on the chromosome level. However, very little work has been done in this family on the molecular level. We are studying the relationships between sibling species in the *Simulium vittatum* and *Simulium pictipes* species complexes, using DNA sequence analysis.

The ribosomal RNA (rRNA) genes provide an ideal system for phylogenetic analysis. Highly conserved genes are interspersed with the rapidly evolving spacer sequences, permitting comparisons to be made at a variety of levels. We are sequencing DNA from the spacer regions of sibling species within the *S. vittatum* and *S. pictipes* complexes which differ in the degrees of cytological relatedness. The DNA sequence data will be correlated with cytological information to form a more complete picture of the evolution within the Simuliidae.

RECENT ADVANCES IN SIMULIID CYTOTAXONOMY IN RELATION TO THE TRANSMISSION OF HUMAN ONCHOCERCIASIS. W.S. Procnunier, Department of Entomology, British Museum (Natural History), LONDON, U.K. SW7 5BD

Cytotaxonomic studies using larval and adult polytene chromosomes (2n=6), have revealed the presence of species complexes within every major Simuliid vector of human onchocerciasis in the Neo and Afro Tropics. Recurrent patterns of chromosome restructuring between complexes, which include 63 taxa distributed across 6 subgenera, suggest that chromosome changes are associated with speciation events similar to those already suggested by previous studies. Application of speciation theory is helping to elucidate the biosystematics of vector groups whose biologies often differ over wide geographic ranges with respect to habitat preference, degree of anthropophily, vectorial competence and insecticide resistance. The adult chromosome technique is proving a successful research tool and should aid in resolving the relative roles constituent cytospecies play in the transmission of onchocerciasis. The optimum time for malpighian chromosome polytenization occurs after a blood meal at the physiological stage when the oocyte is between the pachytene and karyosome stage of meiosis. This technique also facilitates age grading, and the identification of filariae on preserved specimens.

ECOLOGICAL CONSIDERATIONS OF SIMULIIDAE CYTOGENETICS.

Peter H. Adler, Department of Entomology, Clemson University, Clemson, South Carolina 29634 USA

At least half of all North American species of black flies consist of sibling species that are best recognized by cytological criteria. Although nearly all species can be identified reliably by chromosomal characters, cytological identifications often become prohibitive in ecological studies. Therefore, the ability to predict when a black fly morphospecies is composed of two or more sibling species is critically important. I have developed several heuristic guides and a quantitative model for predicting sibling species. The guides are based primarily on the extent to which a morphospecies is distributed over a range of hydrological conditions, particularly channel width and correlated factors. The model is developed from variables involving stream order, voltinism, and geographic distribution, and will provide the probability of a morphospecies consisting of sibling species.

HOST LOCATION AND FEEDING BEHAVIOUR OF ADULT SIMULIIDAE.

James F. Sutcliffe, Department of Biology, Queen's University, Kingston, Ontario, Canada, K7L 3N6

Host location and feeding in black flies are expressions of an overall behavioural "programme" initiated by the insect's first contact with host-related stimuli. For discussion purposes, this is broken down as follows: 1) Activation, 2-4) Long-, Middle-, and Short range orientation, 5) Landing, 6) Probing, 7) Biting, and 8) Active feeding. This paper reviews the sensory and behavioural bases of this programme in black flies. Steps 1-3 are largely dependent on olfactory cues such as carbon dioxide, probably detected by palpal sensilla, and a number of unidentified host-produced volatiles. Flight toward the host appears to be based on positive anemotaxis controlled by optomotor responses. Short distance orientation involves vision more than previous steps although olfactory stimuli continue to play a role. Landing brings the insect under control of contact stimuli sensed through tarsal and mouthpart sensilla and culminates in probing and biting. Biting is accomplished by the syntrophial stylets working in concert with the labium. Blood released by biting from small vessels stimulates mouthpart sensilla by virtue of its ATP content. Resultant feeding is effected by co-ordinated actions of cibarial and pharyngeal food pumps.

HYDRODYNAMICAL ASPECTS OF FEEDING BEHAVIOUR OF LARVAL SIMULIIDAE (DIPTERA). J. O. Lacoursière, Department of Entomology, University of Alberta, Edmonton, Alberta, Canada. T6G 2E3.

Recent studies have shown that hydrodynamic parameters play a major role in shaping the behaviour of lotic organisms such as black fly larvae. Flow complexity over the substrate can change drastically over only few millimeters, hence the site and the way a larva positions itself in the flow can maximize filtration efficacy while keeping the energetic costs, such as drag (shear stress), as low as possible.

Laboratory studies of flow patterns around the body and behaviour of *Simulium vittatum* Zetterstedt larvae attached on two hydrologically defined substrates (a flat plate and a cylinder) show that 1) the labral fans (filtration organs) are always positioned over the boundary layer, 2) by actively deflecting the thorax laterally (yawing) and adjusting the body longitudinal torsion (rotation), the labral fans can be positioned to intercept one or both vortices of the pair generated downstream of the body, 3) with an increase in velocity, the labral fans passively change their configuration (reshaping & deflection), affecting the amount of water passing through them.

Hydrodynamical phenomena influencing assessment of the filter-feeding efficacy of larval Simuliidae will be examined. The use of the boundary layer and separation point by the larvae in drag minimization will be discussed, as well as the needs for research using scaled up models of portions of labral fans.

THE BIOLOGY OF XYLOPHILIC CECIDOMYIIDAE (DIPTERA), Emily Rock* and Dale Jackson, (ER) Wayne General and Technical College, 10470 Smucker Road, Orrville, Ohio 44667, USA; (DJ) Department of Biology, The University of Akron, Akron, Ohio 44325, USA.

The general biology of six Nearctic species of wood vessel-inhabiting Cecidomyiidae is described. Adults have fixed activity periods which vary with species. Females oviposit in exposed, non-decayed hardwood vessels. In all species larval development requires a minimum of 14 days, but emergence from the vessels may be delayed for several weeks. Emergence requires rainfall sufficient to saturate the wood. Pupation takes place in the ground and the length of the period varies with species and sex; the minimum time between generations is 24 days. Larvae develop only in woody angiosperms with vessels of 75µ or greater diameter. Because vessel diameter varies with branch diameter, mature parts of some species of hardwoods may offer suitable niches for larval development while smaller branches may not. Naturally occurring oviposition sites are supplied by storm damage to trees and squirrel nest building. Larvae are parasitized by platygasterid wasps. Symbiotic bacteria associated with the larval, pupal and adult stages are discussed. Techniques for rearing midges in the laboratory are described.

PHYLOGENETIC STUDIES IN DASINEURINI (DIPTERA: CECIDOMYIIDAE): COMPARISON OF THREE SEMAPHORONT SYSTEMS. H.C. Roskam* and S. Kofman, Department of Population Biology, University of Leiden, Schelpenkade 14a, NL-2313 ZT Leiden, The Netherlands.

About 150 species, belonging to the allied genera *Dastneura*, *Jaapiella*, *Macrolabis*, *Wachtliella*, *Bayeria*, *Geocrypta* and *Lathyromyza* have been put in a morphological analysis. We used 50 characters of male, female and larval forms to break up this tribe into some natural clusters. Most genera appear to be monophyletic, although clear-cut delimitations remain difficult and transfers among genera are necessary. The largest entity, *Dastneura*, should be subdivided into two groups, each with a generic status. Phylogenetic aspects of host plant associations will be discussed for the host plant families Leguminosae and Rosaceae, where sequential evolution seems to be common, and for grasses, where associations merely seem to be the result of opportunistic host plant shifts.

POPULATION DYNAMICS OF THE PINE NEEDLE GALL MIDGE, *THECODIPLOSIS JAPONENSIS* UCHIDA ET INOUE (DIPTERA: CECIDOMYIIDAE). K. Soné, Forestry and Forest Products Research Institute, Tsukuba, Ibaraki 305, Japan.

The population dynamics of the pine needle gall midge was studied from 1975 to 1982, and life tables were obtained for six generations. The population of this species was usually maintained at a low level mainly by abiotic factors which operated directly on the midges and was well regulated by the combination of small biotic factors. The limited contribution of biotic factors to the population dynamics of this species may be due to (1) mating, flight, and oviposition are easily affected by temporal weather conditions, (2) the period vulnerable to the attack of natural enemies is very short, and (3) larvae are gregarious in galls.

THE SPERM-STRUCTURE OF THE GALL MIDGE CECIDOMYIIDAE. R. Dallai, Department of Evolutionary Biology, University of Siena, Italy.

It is generally accepted that sperm structure can help to clarify the systematic relationship of those taxa of difficult characterization. Among the gall midge flies of the subfamily Cecidomyiinae, *Contarinia* is retained to be related to the genera of the tribe Cecidomyiini. The sperm structure of several species of this genus, recently examined, confirms, on the contrary, that *Contarinia* must be placed on a separate group together with *Miricomya* and *Lestodiplosis*. All these genera have immotile spermatozoa with flattened tail showing a variable number of plasma membrane evaginations each containing a microtubular doublet devoid of dynein arms.

SILVICULTURAL CONTROL OF DAMAGE CAUSED BY THE JAPANESE CEDAR BARK MIDGE. I. Okochi, Kyushu Branch, Forestry and Forest Product Research Institute, 4-11-16 Kurokami, Kumamoto 860, Japan.

In Kyushu Island, three midge species are economically important for forestry. The Japanese cedar bark midge, *Resseliella odai*, the *Cryptomeria* needle gall midge, *Contarinia inouyei*, and the pine needle gall midge, *Thecodiplosis japonensis*. Among three midges, the Japanese cedar bark midge is the most destructive pest which infesting the main forest tree, *Cryptomeria japonica*. To reduce the damage caused by the midge, pesticide, selection of resistant tree and silvicultural control have been investigated. My study is on the last method.

Thinning is recommended for two reasons. First, it decreases the density of the midge population. However, this population decreases seems to occur only when the microclimate in the stand becomes dry as a result of the thinning. Second, it increases the thickness of the inner bark of the host cedars (or prevents the decline of the thickness caused by competition among trees). This midge kills the cambium from the surface of the inner bark, so if the inner bark is thick enough, it is possible to reduce the stains in the wood caused by the death of the cambium.

THE ANATOMY OF UNUSUAL CECIDOMYIID GALLS. H.G. Larew, Bureau of Science and Technology, Office of Agriculture, Agency for International Development, Washington, D. C. 20523 USA.

Although cecids are known to gall a wide variety of plants and plant parts, we have recently studied two especially unusual galls. One develops on the fruiting structure of an ascomycetous fungus, and is the first cecid gall ever described on such a host. The second is a "big bud" gall of *Populus*. Surprisingly, larvae live in a thick resinous liquid between bud scales in these galls and presumably feed from epidermal nutritive tissues. The anatomy of both of the galls will be described.

STRUCTURAL AND SYSTEMATIC REVIEW OF GEPHYRAULUS RÜBSAAMEN (CECIDOMYIIDAE). E. Sylvé*, Swedish Museum of Natural History, Department of Entomology, S-10405 Stockholm, Sweden, and M. Solinas, Agricultural Entomology Institute, Perugia University, Perugia, Italy.

Three species are here assigned to the genus *Gephyraulus* Rübsaamen. In particular, the genus is characterized by the shape of the female uromeres VII and VIII, together forming (in resting position) a conspicuous swelling containing most of the muscles for the regulation of the movements of the ovipositor. The three species constitute a distinct monophyletic group as indicated by obvious synapomorphies. All these species display a common behaviour as flower bud gall-makers on cruciferous plants.

FUNCTIONAL MORPHOLOGY AND HYPOTHETICAL BEHAVIOURAL MEANING OF ANTENNAL SENSILLA IN CECIDOMYIIDAE LARVAE (DIPTERA).

M. Solinas*, G. Nuzzaci, N. Isidoro, Agricultural Entomology Institute, Perugia University, 06100 Perugia, Italy.

Cecidomyiidae larval antennae, so far considered to be biarticulate, are here indicated as uniarticulate on the base of anatomical evidence. This monomeric antenna rises on a mamelon-shaped protuberance (former "first antennomere", here called antennifer) and bears 5 kinds of sensilla: one large placoid sensillum covering most of the antennal surface, a dorsobasal one (basal sensillum), and an apical sensillum; an intermediate one (sensillum ampullaceum) and a basal, completely internal proprioceptor, both very difficult to detect with a light microscope. Functional morphology of the mentioned sensilla, carried out in scanning and transmission electron microscopy, revealed that: the large placoid sensillum is a multiporous chemoreceptor, most probably olfactory; the basal s. is a mechanoreceptor, probably hygro- or thermoreceptor; the apical s. is a uni-porous chemoreceptor, most probably gustative; the s. ampullaceum is another chemoreceptor, difficult to interpret; the proprioceptor is chordotonal. Some hypotheses about behavioural involvement of these antenna are given.

ECOLOGICAL RELATIONS BETWEEN GALL MIDGES AND THEIR HOST PLANTS. J. Yukawa, Entomological Laboratory, Faculty of Agriculture, Kagoshima University, Kagoshima, Japan 890.

Normally larvae of gall-making cecidomyiids do not leave their galls before maturity. Therefore, in addition to other mortality factors, the fall of galled organs, such as shoots, leaves, flowers and fruits, seems to cause the death of gall midges, more or less severely. The longevity of galled organs is determined also by various factors, among which the gall formation by midge larvae may cause earlier fall of galled organs. Thus, the ecological interrelations are expected to exist between gall midges and their host plants. In association with the population studies on the gall midges inhabiting broad-leaved ever green forest, my collaborators and I have surveyed since 1970 some ecological aspects of their host plants to promote a better understanding of ecological interrelations between them. By analyzing the field data, I am going to discuss an important role of the mutual influences in the natural regulation of the gall midge populations.

MOUTHPARTS AND FEEDING MECHANISM OF THE LARVA OF THE HESSIAN FLY, *MAYETIOLA DESTRUCTOR* (SAY). J. H. Hatchett* and G. L. Kreitner, USDA/ARS and Dept. of Entomology, Kansas State University, Manhattan, Kansas 66506 USA.

Electron microscopy was used to study the mouthparts of the Hessian fly larva to understand the feeding mechanism. Major structures, labrum, mandibles, maxillae, and labium, were identified. Mandible is blade-like, tapers to a grooved tooth and appears to be adapted for piercing. A minute duct passes through the mandible and opens to a hole at the base of the tooth through which salivary fluids may be secreted. Large irregularly-shaped maxillae enclose the lateral aspects of the mandibles. Labium is well-defined, tapers dorsally to a central sclerite and widens ventrally into a deltoid structure. A lobulate hypopharynx arises on the upper surface of the labium. A salivary gland duct opens at the base of the hypopharynx. A tube-like pharyngeal plate transverses the mouth cavity and appears to be an extension of the oesophagus.

Morphology of mouthparts and their arrangement suggests two processes are involved in feeding: Injection of salivary gland substances into the plant via highly specialized mandibles and sucking fluids from tissues through an oesophageal tube. Salivary gland secretions may function in extra-intestinal digestion, inhibiting plant growth, and increasing cell wall permeability allowing removal of liquid food from the plant.

INFRASPECIFIC VARIATION OF THE EUONYMUS GALL MIDGE *MASAKIMYIA PUSTULAE* YUKAWA & SUNOSE (DIPTERA: CECIDOMYIIDAE). T. Sunose, Urawa Gakuin, Daiyama 172, Urawa, Saitama, 337 Japan.

The euonymus gall midge *Masakimyia pustulae* Yukawa & Sunose shows remarkable dimorphism in both larval body colouration and gall thickness. The results of intra- and intertypic crosses concerning the colour dimorphism fit simple Mendelian inheritance. On the other hand, the gall thickness is controlled by polygenes.

The intermediate type concerning the gall thickness is occasionally found in the distributional boundary of the thin and thick types. In places where the two types coexist, a platygastriid adult emerges between the emergence periods of the thin and thick type adults. That is, the parasitism by the platygastriid can act as a temporal isolating factor between them. However, this is not the case when the emergence of the thick type takes place earlier than that of the platygastriid; the result is hybridization followed by the occurrence of intermediate galls. The thin type might have been displaced by the thick one in their contact zone according to the high percentage parasitism of eulophids.

CYTOGENETICS AND GENOME ORGANIZATION OF THE HESSIAN FLY. J.J. Stuart*, Division of Biology, Kansas State University and J.H. Hatchett, USDA, ARS, Dept. of Entomology, Kansas State University, Manhattan, Kansas USA 66506.

The Hessian fly, *Mayetiola destructor* (Say), has been one of the most economically important and extensively studied cecidomyiids. In addition, the identification and study of Hessian fly biotypes demonstrated that the biology of this species is amenable to genetic analysis. However, credible cytological data enabling the comparison of Hessian fly genetics with that of other cecidomyiids was heretofore unavailable. The present studies demonstrated that Hessian fly cytology is more similar to that of other cecidomyiid species than previously believed. The female somatic genome consists of $2n=8$ S-chromosomes, two autosome pairs and two sex chromosome pairs; identified in mitotic and polytene nuclei. The male somatic genome is monosomic for the two sex chromosomes. In addition to the S-chromosomes, germ line nuclei contain 24-40 E-chromosomes which are eliminated from presumptive somatic cells during embryogenesis. Genetic studies indicated that sex determination is conditioned by a single locus with maternal effects which control sex chromosome elimination during embryogenesis. This system of sex determination is responsible for production of monogenous progenies.

THE EARLY STAGES OF GALL MORPHOGENESIS AND LARVAL BEHAVIOR.

O. ROHFRIETSCH, Laboratoire de Cécidologie, UA 1182 CNRS-ULP, Institut de Botanique, 67083 STRASBOURG Cedex FRANCE

The gall results from continual interaction of the host plant and the gall inducing organism. The trigger of gall growth is hypothesized to be situated in the plant defense reactions. By passing the defense reaction, the parasite exploits the growth and differentiation reaction and is able to induce the constitution of its microhabitat. Similarly the parasite is controlled in space and time and is forced to be highly and precisely determined in its behavior and interaction with the host plant.

Gall specificity will be discussed with the example of two Cecidomyid galls: *Didymomyia reaumuriana* and *Physemococcus hartigi*. Both attack the leaf of *Tilia* sp. at the same moment, at the same place. Both insects present a highly specific, precisely determined behavior for oviposition and during the first interactions with the host plant cells (while displaying differences in the intensity of the attack and in the localization of this initial action). This very early plant-insect interaction creates very different situations at the plant level, responsible for different plant responses, leading to totally different gall structures.

Gall specificity is not determined by a specific substance. It results from the specific insect behavior inducing and controlling plant growth.

From the very beginning and all through gall development, gall growth and tissue differentiation reflects and determines insect behavior.

CLASSIFICATION OF CECIDOMYIIDAE (DIPTERA): REACHING TOWARD A CONSENSUS. R.J. Gagné, Systematic Entomology Laboratory, BBI, ARS, USDA, c/o U. S. National Museum NHB 168, Washington, D.C. 20560.

A natural classification of gall midges, particularly of those that feed on plants, is for the most part not feasible. Within tribes one cannot nest most genera with any confidence. Although most genera and species groups are monophyletic, their closest relatives are not apparent either because of unique adaptations that obscure their origins or because they have independently evolved similar characteristics. Although a natural classification is a worthy goal, one must be practical. To be practical a classification must be acceptable and satisfying to most workers on a group. The use of catch-all genera in gall midges must stop as soon as the identity of the type spp. becomes known. Well-circumscribed genera, smaller than most units now used, that are associated with particular host groups may be the most satisfying arrangement because they are the most basic and definable monophyletic group between species and tribe.

THE CARABID FAUNA OF THE NEW ENGLAND MOUNTAINS (COLEOPTERA: CARABIDAE) R.T.Bell, Zoology Department, University of Vermont, Burlington, Vermont 05405-0086 U.S.A.

The New England mountains show a carabid fauna in an early stage of development: the entire area was covered by the continental glacier until about 11,000 years B.P. Several factors have influenced the repopulation of these mountains: the peaks are much higher than those of the Middle Appalachians, and have a true tundra flora and fauna. The tundra occurs in four isolated areas, each with a different selection of Carabid species. The forested zones have a mixture of transcontinental boreal and Appalachian species. A series of valleys isolates the mountains both from the Appalachian mountains and from the Canadian boreal faunas. These barriers affect primarily certain flightless species. A few species are endemic; these must be relicts, and were probably formerly species of the Middle Appalachians.

HISTORICAL BIOGEOGRAPHY OF SAND DUNE TIGER BEETLES IN THE CANADIAN PRAIRIES (COLEOPTERA: CICINDELIDAE).

John H. Acorn, Department of Entomology, University of Alberta, Edmonton, Alberta, Canada, T6G 2E3.

Most dune-dwelling *Cicindela* in the Canadian prairies vary geographically in colouration. Within species, the extent of light elytral markings affects behavioural time budgets and thermoregulation, such that light coloured beetles are more active in hot, sunny conditions, while dark beetles are more active in cool conditions. Expanded light markings may also be cryptic on open sand. The colouration of one subspecies, *C. s. scutellaris*, mimics a meloid beetle associated with one species of dune-stabilizing plant. The present distributions of these taxa have been influenced by changes in the size and extent of open sand, caused by climatic change and human disturbance of sandy habitats. A general model of the historical development of the present geographic ranges and patterns of intraspecific colour variation in these beetles is presented.

THE FAUNA OF LORD HOWE ISLAND AND ITS AFFINITIES. B.P. Moore, Division of Entomology, CSIRO, P.O. Box 1700, Canberra City, 2601, Australia.

Twenty-three species of Carabidae, placed in 20 genera, are known from Lord Howe Island; these have evidently been derived largely from Australian stocks. Eight of the 9 endemic species are flightless geophiles, whereas all but 3 of the 14 species shared with neighbouring regions are capable of flight. However, the presence of a small complement of subapterous Australian species may indicate a closer linkage with the mainland fauna in the past.

In comparison with the larger Norfolk Island, Lord Howe supports a significantly richer but similar carabid fauna. Resemblances and divergencies between these faunas are rationalised in terms of the relative geological ages, isolation and ecological diversities of the parent islands.

ENDEMISM AND BIOGEOGRAPHY AMONG TAHITIAN MECYCLOTHORAX SPECIES (CARABIDAE - PSYDRINI). G.G.Perrault, BP 21, 92292 Chatenay-Malabry Cedex, France.

Mecyclothorax, widely distributed throughout Pacific and Australasian areas, is known only from a few of the numerous Pacific islands. Restricted to mountainous areas, we could expect it to be present on many more "high islands".

In French Polynesia, it is known "officially" only from TAHITI, and from the variations of a small number of anatomic characters, with no evident orderly relationship, we can separate about 70 species from the only 5 (out of a dozen) mountainous areas where more or less collecting has already been done, and we can assume that many more species will be discovered in the future.

Although natural species groups can be defined, a complete phylogenetic diagram cannot be established now, but the influence of some geographic features such as the TAURU valley or the TARAVAO isthmus can be shown, and the TAIARA-PU peninsula appears more or less as a biologically distinct island.

Similarities among *Mecyclothorax* species suggests that the aerial hypothesis for the settlement of the islands is the most probable one. It will include several different waves of immigrants during a period when life conditions *Mecyclothorax* were more favorable at lower altitudes than they are presently.

NEW ZEALAND TIGER BEETLES: THEIR BIOGEOGRAPHY AND EVOLUTION (COLEOPTERA: CICINDELIDAE). R. Anthony Savill, Canterbury Museum, Christchurch, New Zealand.

New Zealand is a small archipelago situated in the south-west Pacific some 2000 kilometres to the east of Australia. Its origin and early separation from Gondwana together with its varied past geography, topography and climate, set ideal conditions for a rich evolution of its own. This is reflected in its very high degree of endemism, over 80% for the flowering plants and well over 90% for its arthropod fauna. Its thirteen species of tiger beetle belonging to the endemic genus *Neocicindela* have evolved to occupy a wide variety of habitats ranging from glacial and volcanic soils, beach and riverbed sands and alpine forest and grassland habitats. In adapting to these varying habitats, many aspects of their biology are unique.

ISLAND-MAINLAND DISTRIBUTION OF CARABID BEETLES ON THE ÅLAND ISLANDS, BALTIC SEA. J. Niemelä, Department of Zoology, University of Helsinki, P. Rautatiekatu 13, SF-00100 Helsinki, Finland.

Carabid beetles were collected by pitfall-traps from several habitat types on islands (8-29 hectares, 2-4 km off the mainland) in the Åland archipelago and Main Åland (mainland, area 900 km²) in the Northern Baltic (about 60°N, 20°E).

The following results emerged: (1) The sample sizes were considerably higher on the mainland than on the islands. (2) There was no clear difference in the species richness between the islands and the mainland. (3) Marked variation was detected in the abundances of some species between the islands and the mainland. For instance, *Patrobus atrorufus* Ström was scarce on the islands, but abundant on the mainland. *Pterostichus melanarius* Ill. was not found on the islands at all, although frequently caught on the mainland. Some species (e.g., *P. niger* Schall) were more abundant on the islands than on the mainland.

No unambiguous explanation for the island-mainland distribution patterns of carabids in the Åland archipelago is at hand. Plausible explanations include: (1) island-mainland habitat variation, (2) differences in dispersal ability, and (3) interspecific interactions (e.g., possible competition between *P. niger* and *P. melanarius*).

RELATIONSHIPS AND DIFFERENTIATION OF TAXA IN THE WEST INDIES AND MEXICO (COLEOPTERA: CARABIDAE). G.E. Ball, Department of Entomology, University of Alberta, Edmonton, Alberta, Canada T6G 2E3.

Reconstructed phylogenies and zoogeographic patterns of selected groups of carabid beetles (Pterostichini, Harpalini, Lebiini, and Galeritini) are used to assess the dynamics of Darlingtonian zoogeography in contrast to the statics of vicariance biogeography as explanatory models for the origin and evolution of the West Indian biota, and that of the Mexican highlands.

HISTORICAL BIOGEOGRAPHY OF WEST INDIAN TIGER BEETLES. R. Freitag*, Department of Biology, Lakehead University, Thunder Bay, Ontario, Canada P7B 5E1, and R.R. Murray, 107 Thomas Place, Fort Worth, Texas 76107.

Three species of Megacephala and fourteen species of Cicindela are found in the West Indies. All species, including six endemics, inhabit the Greater Antilles, and six species of Cicindela inhabit the Lesser Antilles. Major centres of species concentration are Cuba and Hispaniola. Most taxa have phylogenetic affinities with Middle American groups. Middle American origins are proposed for the main components of the West Indian tiger beetle fauna.

GEOGRAPHICAL ISOLATION AND RATES OF KARYOTYPIC EVOLUTION IN CARABID BEETLES (COLEOPTERA, CARABIDAE). J. Serrano, Departamento de Biología Animal y Ecología, Facultad de Veterinaria, 30071 MURCIA (Spain).

Relationships between the degree of geographic isolation and the rate of karyotypic evolution vary widely depending on the taxon considered. **A) Species-groups isolated in mountains:** This situation is thought to favour moderate to high rates because of restricted gene flow, low deme size, etc. This seems to be true for species belonging to genera such as Calathus, Amara, Zabrus and Brachinus. However, in others like Carabus and Bembidion orophilous species have the same chromosome number than those of lowlands and plains, i. e., restrictions to change overcome the effects of isolation. **B) Species-groups showing little geographic isolation:** In groups with present large distributional areas it is expected lower rates than in the former ones. This seems to be true with regard to Calosoma, Trechus, Pogonus, Harpalus or Chlaenius, but again there are many exceptions, as in Nebria, Agonum or Syntomus.

It is therefore concluded that among carabid beetles rates of karyotypic change are primarily controlled by endogenous factors concerned with karyotype architecture and functionality rather than by external ones such as those derived from geographic isolation.

LARVAL CHAETOTAXY ANALYSIS AND PHYLOGENY OF HYDROPORINAE (COLEOPTERA: DYTISCIDAE).

Y. Alarie*, Département de Sciences Biologiques, Université de Montréal, Québec, Canada, H3C 3J7.

Classifications of Hydroporinae (Coleoptera) proposed until now have been based principally on adult characters. Though little studied, larvae represent a new and important source of data for systematic studies. Chaetotaxy analysis in particular has been shown to be very useful in characterizing taxa, in reconstructing phylogeny, and in building classifications in many different families of Coleoptera.

We present here the first results of an investigation of the chaetotaxy of the legs of North American Hydroporinae tribes and genera. An attempt to reconstruct the phylogeny of these taxa is undertaken.

A PHYLOGENETIC AND ZOOGEOGRAPHIC ANALYSIS OF LACCORNIS GOZIS (COLEOPTERA: DYTISCIDAE) WITH THE DISCUSSION OF A NEW MONOBASIC TRIBE FOR LACCORNIS. G. William Wolfe*, Department of Entomology, Rutgers University, New Brunswick NJ 08903 and R. Roughley, Department of Entomology, University of Manitoba, Winnipeg MB R3T2N2.

A new monobasic tribe is proposed for *Laccornis*. Phylogenetic and zoogeographic analyses demonstrate that members of *Laccornis* form the most plesiotypic clade of Hydroporinae. Ten species are assigned to *Laccornis*. Three species groups are recognized within the genus. Species group I is monobasic and contains only the European species, *L. kocai* (Ganglbauer); it represents the sister clade to the remainder of *Laccornis* and was probably isolated in the early to mid-Cretaceous. Species group II has three species; the most plesiotypic is the Holarctic *L. oblongus* (Stephens) and the more derived Nearctic species, *L. conoideus* (LeConte) and *L. pacificus* Leach. These species were isolated in Asia-America by the late Cretaceous - early Cenozoic intercontinental seaway.

Species group III is the sister group to species group II and contains *L. deltoideus*, *L. n.sp.* (cf. *L. deltoideus*), *L. latens*, *L. difformis* (LeConte), *L. schusteri* Wolfe and Spangler, and *L. etnieri* Wolfe and Spangler. The ancestral stock of this species group was isolated in Euramerica in the late Cretaceous.

CHARACTERIZATION OF THE BIDESSINI (COLEOPTERA, DYTISCIDAE). O. Biström, Zoological Museum, University of Helsinki, Finland.

The tribe Bidessini, with about 530 recognized species, was recently reviewed, because of confusion on species-, genus and tribus level. The existing confusion is probably caused by e.g. the wide distribution of the tribe, the big species number, and the small body size. My main purposes were to examine the delimitation of the different genera attributed to the Bidessini, and the delimitation of the tribe itself. Over 20 characteristics were examined, including both external and genital features, and at least the type species of each genus was examined.

Concerning the delimitation of the Bidessini I regard the segmented paramere to be the key-characteristic for the tribe, and this excludes a few genera previously at least sometimes attributed to the Bidessini. At present I recognize 30 genera in the tribe, but some of them (*Uvarus*, *Liodessus*, *Bidessus*, *Leiodytes*, *Clypeodytes*) undoubtedly are in great need of a total revision.

ECOLOGICAL ADAPTATIONS FOR SURVIVAL IN AGABUS DISINTEGRATUS (CROTCH) (COLEOPTERA: DYTISCIDAE) IN CALIFORNIA. R. Garcia and K.S. Hagen, Division of Biological Control, University of California, Berkeley, California 94720, USA.

Agabus disintegratus adults undergo an aestival diapause in the root system of plants in the basins of dried ponds. Permanent natural water sources are scarce due to California's Mediterranean climate and those that do exist most likely contain predators and competitors. This strategy avoids the need to seek out and compete for these limited resources. Mating, oviposition and development are geared to the late fall and winter months with dispersal flight apparently restricted to the winter months when water sources are most common.

ODONATE - DYTISCID BEETLE INTERACTIONS: CO - OCCURRENCE PATTERNS IN BOG POOL HABITAT. D. J. Larson, Department of Biology, Memorial University St. John's, Newfoundland, Canada A1B 3X9.

Odonate larvae and dytiscid beetles are dominant taxa within the invertebrate predator guild of shallow lentic habitats. These taxa potentially interact through predation and competition. The energetically efficient predation strategy of odonates suggests they negatively impact on dytiscids in situations of co-occurrence and that dytiscids should generally avoid habitats occupied by odonates. The pattern of habitat use by odonates and dytiscids was examined by quantitatively sampling invertebrate populations in a series of small Newfoundland bog pools. Generally there was a significant negative correlation between odonate and dytiscid density, with beetles predominating in smaller pools. The few beetle species positively correlated with odonates had adaptations or behaviors that possibly protect them from predation. Feeding studies found evidence of odonates preying on dytiscids, but not the converse. Other observations and speculations on habitat partitioning between these taxa are presented.

NUMERICAL ANALYSIS OF SELECTED AQUATIC HABITATS BASED ON OCCURRENCE OF DYTISCID SPECIES. G. William Wolfe, Department of Entomology, Rutgers University, New Brunswick NJ 08903.

Over 297 collections of dytiscids were made in North America (emphasizing Tennessee and the southeast). Each locality was classified into one of eleven habitat types (without knowledge of locality specific species lists). Habitats were then compared by clustering, canonical discriminant analysis, and rarefaction techniques. Most results indicated that lotic habitats and temporary pools were the most distinct habitat categories and formed two ends of a spectrum, with permanent lentic habitats variously arrayed between.

Assessing species richness is complicated by the fact that species richness is correlated with sample size; i.e. samples with greater numbers of specimens tend to have more species. To compensate for this, "diversity" was evaluated by a rarefaction analysis of the expected vs. observed number of species for each habitat. The only habitats with fewer species than expected were streams, ponds, and temporary open-field ponds; no habitat was more species rich than expected by chance alone. Expected vs. observed species/genus (S/G) ratios also were computed. The S/G ratio was lower than expected for temporary open-field ponds and higher than expected in streams.

THE MATING BEHAVIOUR OF A BOREAL WATER BEETLE, *DYTISCUS ALASKANUS*. Ronald B. Aiken, Department of Biology, Mount Allison University, Sackville, New Brunswick, Canada E0A 3C0.

Dytiscus alaskanus is a common aquatic beetle living in eutrophic ponds throughout western Canada. In spite of its ubiquity and the prevalence of other dytiscids in the aquatic insect fauna, very little is known of the mating behaviour of any species in this family. During the mating season (May and June), pairs of *Dytiscus alaskanus* were taken from the field and placed in small aquaria. Behaviour was recorded on a time lapse VCR and analysed frame-by-frame. There are three periods in a mating sequence: precopulation, copulation and sperm transfer, and post-copulatory guarding. There is no recognizable courtship. Males grasp females with their mating pads and attempt to mate immediately. Copulation and sperm transfer are accomplished within the first hour. There then follows a period of up to 10 hours of post-copulatory guarding. These data will be discussed with reference to sexual selection and the relative investment of each sex in mating.

PARTIAL CHARACTERIZATION AND SEASONAL VARIATION OF THE GROSS BIOCHEMICAL MAKE-UP OF *DYTISCUS ALASKANUS* ACCESSORY GLAND CONTENT. Alison E. Bartlett, John M. Stewart* and Ronald B. Aiken, Department of Chemistry, Mount Allison University, Sackville, New Brunswick, Canada E0A 3C0.

Animals were harvested from George Lake, Alberta over the period April to August, 1987. The accessory glands were removed and analysis was done "in the field" at the University of Alberta, Department of Entomology Field Station at George Lake. The components assessed were total levels of carbohydrate, protein, free amino acid, lipid and phenolics. The significant variations of components over the mating season will be discussed in relationship to accessory gland development and time into mating season. Results of further analysis of the protein fraction and free amino acid fraction will be presented.

TWO NEW GENERA OF CAVERNICOLOUS WATER BEETLES FROM ASIA (COLEOPTERA: NOTERIDAE; DYTISCIDAE). Paul J. Spangler, Department of Entomology, National Museum of Natural History, Smithsonian Institution, Washington, D.C. 20560.

During biospeleological investigations of Mananga Cave in Indonesia and Kubio Cave in Thailand, spelunker Anne Bedos collected a new aquatic beetle genus and species in each cave. The minute new taxon from Indonesia is the second known stygobiontic noterid genus and species; it belongs to the tribe Notomicrini and seems most similar to the genus *Notomicrus*. Characters separating the two noterid genera are discussed. The new taxon from Thailand is the ninth dytiscid genus and species known from subterranean waters and belongs to the subfamily Hydroporinae and tribe Hydroporini. In some characters, probably because of convergence, it resembles the stygobiontic *Moriomotoa* from Japan but its relationships are unclear. Both genera were examined using a scanning electron microscope and are illustrated by slides of micrographs and line drawings.

A REVIEW OF THE NEOTROPICAL AQUATIC BEETLE GENUS *BIDESSONOTUS* (COLEOPTERA: DYTISCIDAE). Frank N. Young, Department of Biology, Indiana University, Bloomington, Indiana 47405, USA.

Keys and figures are given for the determination of species of the Neotropical aquatic beetle genus *Bidessonotus* with descriptions of new species.

USE OF COXITES AND SECONDARY SEXUAL CHARACTERS TO IDENTIFY FEMALE *GYRINUS* IN EASTERN NORTH AMERICA (COLEOPTERA: GYRINIDAE). W.L. Hilsenhoff, Department of Entomology, University of Wisconsin, Madison, WI 53706.

The taxonomy of North American *Gyrinus* has received little attention since a revision by H.C. Fall in 1922. Fall and subsequent workers believed that while males can be identified by their distinctive genitalia and certain other characters, females of several species can be identified only by associating them with males. Since schools of *Gyrinus* often contain several species, identification of females by association may frequently lead to error. While seeking ways to sort and identify females in large collections, I discovered that the shape and size of the coxites varied greatly among species, and that the last abdominal sternum of females was also modified and frequently differed markedly from one species to another. By using these two characters, some non-sexual characters, and elytral microsculpture, which differs from that of the male, it is possible to identify females as accurately as males. The coxites of Gyrinidae are large, broad, sclerotized structures that are easily extruded for study, making them extremely useful for identification.

ON THE SYSTEMATIC POSITION OF THE FAMILY GYRINIDAE (COLEOPTERA: ADEPHAGA). R.G. Beutel* and R.E. Roughley, Inst. f. Biol. II (Zool.), RWTH Aachen, D-5100 Aachen, West Germany.

Various characters of adult and larval members of Adephaga and Cupedidae were analyzed, and suggest that the Gyrinidae are the sister group of the remaining Adephaga, and not closely related with the other aquatic families. Noteridae, Amphizoidae, Hygrobiidae, and Dytiscidae seem to form a well founded monophyletic unit. The hypothesis of a very isolated position of Gyrinidae is supported by morphological characters, by chemical data on defence gland constituents, and the old age of the group documented by a larva found in upper Permian deposits.

TAXONOMY, DISTRIBUTION, AND PHYLOGENY OF NORTH AMERICAN *GYRINUS* GEOFFROY (COLEOPTERA: GYRINIDAE). S.Oygur*, and G.W.Wolfe, Department of Entomology, Rutgers University, New Brunswick, New Jersey 08903, USA.

The Nearctic species of *Gyrinus* Geoffroy are revised; Thirty nine species are assigned to *Gyrinus* after ten synonyms were established and two Palearctic species, *Gyrinus marinus* and *G. aeratus*, are recorded in the Nearctic region for the first time. In the eastern half of North America, the most speciose region is in the northeast; in western North America the most speciose region is centered in British Columbia.

The phylogenetic position of *Gyrinus* in Gyrinidae is re-investigated by using characters in Hatch (1925), Balfour-Browne (1950), Brinck (1955), and Larsen (1966), with *Spanglerogyrus* as the out-group. Most data indicate that *Orectochilini* is more plesiomorphic than and sister to the clade that includes Gyrinini and Enhydrini. A preliminary phylogenetic hypothesis for species of *Gyrinus* also is constructed stressing Nearctic species; this phylogenetic analysis is inconclusive but suggests four polychotomys. Monophyly of these groups primarily is established by abdominal coloration and aedeagal structure. Two sub-groups based on leg and tarsal claw coloration are proposed within third and fourth clades.

A STUDY OF THE BIOLOGY OF INDIAN CHRYSOMELIDAE (COLEOPTERA): A REVIEW. J.P. Singh, Zoology Department, Punjabi University, Patiala (Punjab), India.

The family Chrysomelidae presents a lot of morphological and behavioural diversity as well as developmental peculiarities. The larvae and adults of the majority of the species feed on and inhabit leaves, soft stems or roots (Galerucinae); infest submerged parts of aquatic plants (Donaciinae); infest aquatic plants above water or terrestrial plants (Criocerinae); mine leaves, tender stems, or branches of trees (Alticinae); inhabit roots or soil (Eumolpinae); are free leaf feeders (Chrysomelinae); or feed totally on roots (Sagrinae). In fact, different developmental patterns warrant a thorough probe into the feeding and nonfeeding intervals of the pest species to know their potential for economic importance. A study on the biology under the prevailing ecosystem, therefore, becomes essential. Such a study has been made on the pest species of the genera *Aulacophora* Chevrollet, *Altica* Fabricius, *Cassida* Linnaeus, and *Oocassida* Weise. A complete review of the literature for pest species of this continent has been prepared.

RING DEFENSE STRATEGY AMONG BRAZILIAN CHRYSOMELID LARVAE (COLEOPTERA). J. Vasconcellos-Neto and P. Jolivet*, (JV-N) Departamento de Zoologia, Universidad Estadual, Campinas São Paulo 13081, Brazil; (PJ) 67 Boulevard Soult, 75012 Paris, France.

Ring defense strategy or cycloalexy, a completely new concept, seems to be rarely used by a few chrysomelid larvae belonging to the Galerucinae (*Coelomera* spp.), Chrysomelinae (*Platyphora corviva* Stal) and Cassidinae (*Chelymorpha informis* Boheman). All the reported observations have been done in Brazil, but the behaviour is probably much more widely distributed. Until now, only the above species have been recorded, but among the Galerucinae the genus *Dircema*, feeding like *Coelomera* on *Cecropia*, perhaps shows the same behaviour. *Platyphora corviva* seems unique among the 400 species so far described, but there must be some more species still unobserved. *Chelymorpha informis* probably derives her special behaviour from other Stolinae showing maternal care of eggs and larvae. For instance, larvae of *Echoma flava* (L.) are known in Argentina to produce two rings on the host plant, rings watched carefully by the mother.

GROWTH, DEVELOPMENT AND SURVIVAL RATE OF THE WILLOW LEAF BEETLE, MELASOMA 20-PUNCTATA (COL., CHRYSOMELIDAE) FEEDING ON DIFFERENT SALIX SPP. W. Topp⁺ and P. Beracz, Physiological Ecology Section, Department of Zoology, University of Köln, Weyertal 119, D-5000 Köln 41

All activities of the univoltine *M. 20-punct.* occur in a restricted period of spring, and are followed by a long dormant phase of aestivo-hibernation. The order of food plant preference was as follows: *S. fragilis* > *S. viminalis* > *S. alba* > *S. caprea*.

The host plant species had no effect on the developmental period, on the survival rate and on the size of the immature stages. On the other hand mortality of adults during aestivo-hibernation was different. It was predominately a consequence of food plant selection and pattern of herbivore attack during the foregoing season. In addition, phenotypic variability within populations influenced survival rate. Defensive responses of host plants in the mean reduced population density by 60%. However, in some cases total extirpations of leaf beetle populations also occurred. Defence strategies of host plants would be circumvented if *M. 20-punct.* could manage to develop earlier in the spring.

ELECTROPHORETIC PATTERN OF THE MID-GUT ENZYMES AND CHANGES IN THE PATTERN IN ADULT DIAPAUSE IN ASPIDOMORPHA MILIARIS F. (COLEOPTERA : CHRYSOMELIDAE). K.K.Verma* and R.K.Shrivastava, Department of Zoology, Government Arts and Science College, Durg, M.P., 491001, India.

Electrophoretic pattern of proteins in the mid-gut extract of *A. miliaris* has been worked out through gel electrophoresis, and among the discs in the pattern those representing proteases, lipases and amylases have been identified. It has been found that in summer adult diapause all discs disappear except the lower-most disc representing amylases. The reverse has been found in the winter adult diapause, when the only disc, which has disappeared, is the last disc.

THE EFFECTS OF HOST PLANT DENSITY AND DIVERSITY ON ALTICINE POPULATIONS AND PATTERNS OF HERBIVORY IN A COSTA RICAN RAIN-FOREST. C.N. Duckett, Department of Entomology, Cornell University, Ithaca, N.Y. 14853 USA

Specialized herbivores often feed on uncommon plants and their numbers may be determined by the density of host plant available, however, their populations can also be affected by other herbivores eating their host. A monophagous Alticine (Coleoptera: Chrysomelidae), genus unknown, feeds solely on *Passiflora pittieri*, a woody liana, uncommon in lowland Central America. *P. pittieri* is also fed upon by up to 12 other species of Alticine oligophagous on 8 other local species of *Passiflora* in Corcovado National Park, Costa Rica. The effects of density of *P. pittieri* and diversity of other *Passifloras* on the number and diversity of monophagous and oligophagous Alticines were studied. The effects of grazing by the monophagous species was compared to the effects of grazing of oligophagous species at high and low beetle densities. Implications for tropical plant sparseness as maintained by insect herbivory are discussed.

LEAF-BEETLE COMMUNITY STRUCTURE IN AN AMAZONIAN RAINFOREST CANOPY. B.D. FARRELL*, Department of Entomology, University of Maryland and T.L. ERWIN, Department of Entomology, Smithsonian Institution.

A tropical rainforest canopy is arguably the most complex and poorly known ecosystem in the world. Basic description of the intricate trophic webs of the plant/herbivore/predator assemblages such canopies represent is in still-nascent stages. Here we apply contrasting approaches extant in the current literature to probe for the first time the insect community structure of one such Amazonian rainforest canopy. We have analyzed the canopy-distributions of the two most species-rich, trophically different insect groups (the folivorous chrysomelid leaf-beetles: 126 "common" species and the predaceous staphylinid rove-beetles: 72 "common" species). We document a strong "species/architecture" effect on the richness and abundance of the canopy rove-beetle community while leaf-beetle diversity seems more an aggregate function of numerous specialized "component" communities. We suggest that the role that "size-related" variables play in determining the diversity of plant faunae varies with trophic status and, by extension, with the nature of the interaction.

THE CHRYSOMELIDAE OF *CECROPIA* (CECROPIACEAE), A STRANGE COHABITATION. Pierre Jolivet, 67 Boulevard Soult, 75012 Paris, France.

Several Chrysomelidae feed on *Cecropia* (or on *Pourouma*) (Cecropiaceae) in the Neotropical region and some of them, the *Coelomera* (Galerucinae) are narrowly adjusted to their host-plant. On myrmecophilous *Cecropia*, several species of *Coelomera* (Andrade, 1981) pierce the prostoma of the internode like the *Azteca* queen and lay 60 to 70 eggs inside. Other species lay eggs under the distal region of the leaflets. The eggs there are much less protected from predators, except for myrmecophobic species of *Cecropia*. Larvae are protected by behavioural defense and enteric discharge, and adults by reflex bleeding. *Coelomera* adults feed on Müllerian bodies of the trichillum and on young leaves, but probably not like the ants do, on female flower nectaries and pearl bodies. *Coelomera* are peacefully cohabiting with the *Azteca* like other Chrysomelidae such as *Cacoscelis* (Alticinae), *Metaxytera* and *Sceloeropia* (Hispiinae). Hispine larvae are leaf miners under the extremity of the leaflets of the host plant, and the eggs are laid inside a theca inserted into the mesophyll. The biology of *Dircema* (Galerucinae) on *Cecropia* is still unknown, but probably very similar to *Coelomera*.

PHENOLOGY AND HOST PLANT FEEDING PREFERENCES OF *MONOXIA* N. SP. (COLEOPTERA: CHRYSOMELIDAE: GALERUCINAE). Jorge A. Santiago-Blay, 218 Wellman Hall, Department of Entomological Sciences, University of California, Berkeley, California 94720, USA.

A possible new species of *Monoxia* lives in salt marshes of the San Francisco Bay area (California, USA). Larvae are leaf miners of *Grindelia humilis* (Asteraceae). In laboratory rearings, pupation takes place within or outside mined leaves. Adults are more abundant in summer and fall and seem to have a narrow host plant feeding range. In addition to its natural host plant, adults feed significantly only on another species of *Grindelia* among more than 12 species of Asteraceae tested.

SOME FACTORS INCLUDING NEMATODES INFLUENCING THE POPULATION LEVELS OF PAROPSINE CHRYSOMELID BEETLES. B.J. Selman, Department of Agricultural and Environmental Science, University of Newcastle upon Tyne, England, NE1 7RU.

The population levels of paropsine chrysomelid beetles are subject to large fluctuations. These have peaks at long time intervals possibly of approximately 12 years. Population peaks are followed by sudden declines to very low levels. The factors controlling these population changes are many. Population rise is stimulated by foliage quality and type, controlled in turn by factors such as nutrient availability, pollution, weather, forest disturbance and regeneration after fire or pest attack. Population growth is limited by egg and larval parasites, predation especially by coccinellid beetles and interspecific competition. At times of peak populations 100% of sampled larvae of *Chrysophtharta cloelia* and other paropsine species were found to be infected with myrmithid nematodes. The mortality produced by these nematodes depends on the rate of development of the host which also determines the stage of the host when the adult parasite emerges. Emergence from an early instar almost always results in the death of the host while the host usually survives when the parasite emerges from an adult. Nematodes are highly effective in suppressing pest outbreaks of many species of leaf feeding chrysomelids in Australia. This appears to be very unusual, for nematodes are seldom considered to be effective in controlling populations of leaf feeding insects.

POLLEN FEEDING IN ALTICINAE (COLEOPTERA: CHRYSOMELIDAE). G. A. Samuelson, Department of Entomology, Bishop Museum, Honolulu, Hawaii, USA 96817.

Pollen feeding in Alticinae at the generic level is rare, with adults in *Nonarthra* and *Arsipoda* so identified to date. *Nonarthra* commonly shows positive for pollen. It is a highly specialized genus, different in many characters from other Alticinae, and is also divergent in its apparent specialization for pollen. *Arsipoda* has shown positive for pollen in certain species from New Caledonia and includes examples collected from flowers of Winteraceae.

Pollen was found in large amounts in the alimentary canals of *Nonarthra cyaneum* Baly from Japan, *N. variabile* Baly from China, Taiwan, and India, and *N. sp.* from New Guinea. Pollen was packed densely in the gut in most of the individuals dissected. In *N. sp.*, the pollen appeared dispersed throughout most of the abdomen, suggesting that the gut was expanded to hold the large amounts of pollen. Individual insects appeared to have pollen from a single plant species. Examples of *N. variabile* sometimes contained a different kind of pollen from one locality to another. The pollen found in *N. sp.* is identified as *Canna indica* L., Cannaceae, by host association. The other plant species remain unidentified.

HOST PLANT AFFINITY IN RELATION TO PHYLOGENY OF *LEPTINOTARSA* BEETLES. T. H. Hsiao, Department of Biology, Utah State University, Logan, Utah 84322-5305, U.S.A.

The leaf-beetle genus *Leptinotarsa* comprises of about 45 species of Neotropical origin. Host plant specificity, geographical distribution and bionomics of nearly half of these species have now been investigated. All species are restricted feeders specializing on plants of one of three plant families--Solanaceae, Compositae and Zygophyllaceae.

Adaptation to these plants influenced the life history pattern and biology of these beetles. Herbaceous feeders exhibited a shorter developmental duration than species fed on perennial woody plants. Some species from cooler Nearctic region have evolved hibernant adult diapause below ground to ensure survival and synchronization with availability of their food plants. Species in warmer climates entered an aestival diapause induced by unfavorable host conditions or food shortage. Available information on bionomics, distributional patterns, external morphology, chromosomal karyotypes, and isozyme patterns were used to assess relatedness among these beetles. Correlation between host plant affinity and phylogeny of *Leptinotarsa* beetles will be discussed.

DEFENSIVE GLANDS AND SECRETIONS AS TAXONOMICAL TOOL IN THE CHRYSOMELIDAE. J.M. Pasteels, Laboratoire de Biologie Animale et Cellulaire, Université Libre de Bruxelles; 50, Av.F.D. Roosevelt, 1050 Bruxelles, Belgium.

The comparative morphology of defensive glands and the chemical nature of the secretions will be discussed in terms of their value as taxonomical criteria for chrysomelids. The morphology and chemistry of glands of larvae have evolved differently and independently from those of adults, giving complementary information.

Also, within adults, the morphology and chemistry of glands have evolved at different rates. Glands tend to evolve more slowly and hence provide information about affinities at higher taxonomic levels (subfamilies); whereas secretion's chemistry has evolved more quickly and provides like information at the level of genera and subtribes. The value of gland morphology and chemistry for resolving taxonomic affinity as opposed to convergent similarity is discussed with regard to concordance with current schemes of classification of Chrysomelinae.

RECENT ADVANCES IN CYTOGENETICS AND CYTOTAXONOMY OF THE LEAFBEETLES. E. Petitpierre*, Lab. Génétique, Dep. Biología, 07071 Palma de Mallorca (Spain).

Over 750 species, subspecies and chromosomal races of the leafbeetles are known to date on cytogenetic grounds. They exhibit the highest heterogeneity of diploid numbers and sex-chromosome systems so far found within the beetle families. There is not a clear modal value for the whole chrysomelids though most subfamilies have characteristic peak numbers. The possible interrelationships between subfamilies of chrysomelids based on these modal values, are also discussed taking into account other aspects of phylogenetic interest. Preliminary results on the C-banding in the leafbeetle chromosomes point out their slight or even null appearance, and their almost constant location close to the centromeres. The DNA content of spermatids in the leafbeetles displays a striking interspecific variation and may provide a valuable tool to improve our evolutionary knowledge on them.

PROBLEMS IN THE CHRYSOLINA AURICHALCEA SPECIES COMPLEX (COLEOPTERA: CHRYSOMELIDAE). SHIZUO FUJIYAMA, Department of Biology, Faculty of Science, Shinshu University, Asahi, Matsumoto, 390 Japan.

Chrysolina aurichalcea has a wide distribution from Oriental region to Palaearctic region. There are many studies concerned with the phenotypic frequency of the two colour forms, and the studies have shown that the frequencies vary with the local populations. These seem to mean the existence of large variation in this species. Cytogenetically, four types of diploid chromosome numbers have been known. And further, other two types were recently found by us. These raise the species problems. Consequently, the characters of these populations are reexamined from various view points.

The populations having different chromosome numbers usually showed allopatric distributions in each other, though some showed sympatric ones. No strong connections between the chromosome numbers and the phenotypic frequencies of the two colour forms were seen. The karyotypes were not so close to each other, even though the populations with these different chromosome numbers have been treated as the same species. Comparisons of morphological and genetic characters of these populations showed slight differences. Their crossings showed almost normal survival rate in F_1 but considerable reduction of it in F_2 . These results suggest the existence of more than two sibling species.

SOME ASPECTS OF CHROMOSOMAL EVOLUTION IN PALEARCTIC ALTICINAE (COLEOPTERA: CHRYSOMELIDAE). C. Segarra* (1), E. Petitpierre (2). (1) Dpt. Genética. Fac. Biología. Univ. Barcelona. 08028 Barcelona. Spain. (2) Dpt. Biología. Fac. Ciencias. Univ. Balears. 07071 Palma de Mallorca. Spain.

The chromosome numbers and sex determining systems have been studied in nearly seventy species included in 15 different genera of Palearctic flea-beetles. The frequency distribution of male chromosome numbers does not show a clear modal value though $n=15$ is the most common haploid complement. The distribution is asymmetric with a great number of species that present haploid values lower than $n=15$. These data together with those found in other species mostly of the Neotropical fauna, give a total of more than 200 species of Alticinae with a known karyotypic formula. However, in spite of the large sample analyzed there is not a clear basic chromosome number that were at the same time the most widespread and frequent. This result contrasts with which happens in other subfamilies of Chrysomelidae, as for instance in the Chrysomelinae. Most of the analyzed genera present peculiar cytogenetic characteristics that confirm their identity and lead to the suggestion that the ancestral karyotypic formula for each genus can be quite different from one to another and respect to the considered ancestral for the subfamily. These facts coupled with the intrageneric tendencies of chromosomal evolution will be discussed.

THE GENUS PHAEDON (COLEOPTERA: CHRYSOMELIDAE) IN MIDDLE AMERICA. E.U. Balsbaugh, Jr., Entomology Department, North Dakota State University, Fargo, North Dakota 58105, USA.

The genus *Phaedon* (Coleoptera: Chrysomelidae) in Middle America is composed of at least five species: *P. cyanescens* Stal, *P. fuscipes* Stal, *P. fuscum* Jacoby, *P. splendicans* Stal and *P. varicolor* Jacoby. Two species of western or southwestern United States, *P. prasinellus* (LeConte) and *P. purpureus* (Linell), possibly also extend into northern Mexico. If *P. ruficeps* Achard, described from Costa Rica, is a valid species, the total number of *Phaedon* from Middle America would be eight. However, types or other authentically determined specimens of *P. ruficeps* could not be studied. Based strictly on description, *P. ruficeps* is suspected to be a junior synonym of *P. fuscum*. These species are classified in three subgenera: *Phaedon* (s. str.), *Allophaedon*, and *Orthosticha*. *P. mexicanum* Jacoby and *P. nigripes* Jacoby are new synonyms of *P. fuscipes* and *P. seticornis* a new synonym of *P. varicolor*. Descriptions, measurements, distributions, maps, seasonal occurrence, and discussion are presented for each species. A key to species is given.

THE GENUS VALUE IN CHRYSOMELINAE (COLEOPTERA: CHRYSOMELIDAE). M. Daccordi, Museo Civico di Storia Naturale, Lungadige P. Vittoria 9, 37129 Verona, Italy.

The genera of the subfamily Chrysomelinae are classified as such on the basis of characters the authors consider to be of primary discriminating value. A critical investigation of these characters made on all the known genera has convinced me that many of these are not very reliable. Since the character is also a key to functional peculiarities, its significance may differ according to the groups. Epipleura ciliation helps characterize the subtribe Chrysolina; while in the Paropsina, where it defines the subgenera, it has slight significance; and its significance is lowest amongst the Entomoscelina, as it discriminates only a few of the species. The shape of the claws changes according to the life led on leaves and cannot have phylogenetic importance. Thus a rating of the characters must be made for each group on the basis of morpho-physiological data in relationship with the environment.

METAFEMORAL SPRING STUDIES OF SOME NEOTROPICAL GENERA OF ALTICINAE (COLEOPTERA: CHRYSOMELIDAE).

D.G. Furth, Peabody Museum, Yale University, New Haven, Connecticut 06511 USA.

Examination of the metafemoral spring in a variety of Neotropical genera was undertaken in order to further the study of this internal generic level character and to relate some Neotropical genera to the previously established metafemoral spring morpho-groups from Palearctic and Nearctic Regions. Although this study concerns only a small proportion of the approximately 200 genera of Neotropical Alticinae, it does elucidate the relationship of certain genera and groups of genera. Study of other generic level morphological characters such as male and female reproductive structures increases the security of establishing generic group relationships. It is evident that most subfamily group names, especially tribes, used in the past have little foundation and their use only adds confusion to research on systematics and phylogeny of Alticinae.

INTERNAL REPRODUCTIVE ORGANS AND THEIR TAXONOMIC SIGNIFICANCE IN THE FAMILY CHRYSOMELIDAE (COLEOPTERA) - H. R. PAJANI, ZOOLOGY DEPARTMENT, PANJAB UNIVERSITY, CHANDIGARH, INDIA.

Observations on the reproductive system of nearly 100 species show important variations in the number of testes, structure of the accessory glands, length of the ejaculatory duct, length of ovarioles, shape and size of the spermatheca and presence or absence of bursa copulatrix. These also reveal close relationship between subfamily Alticinae and Galerucinae; Clytrinae and Cryptocephalinae; Cassidinae and Hispinae; Eumolpinae and Chrysomelinae. There is also reflected some cross similarity among the above four groups on the basis of two pairs of testes. Criocerinae, on the other hand, appears to form an exclusive group in this family. The significance of these findings in the taxonomy of the group as well as its affinities with family Bruchidae will be discussed. Possible co-relation between the superfamilies Chrysomeloidea and Curculionoidea will also be commented upon.

CHARACTER CORRELATION IN THE INTERNAL REPRODUCTIVE SYSTEM OF THE FAMILY CHRYSOMELIDAE (COLEOPTERA). K. SUZUKI, Department of Biology, College of Liberal Arts, Toyama University, Gofuku, Toyama, Japan 930.

Various types of character correlation are widely recognized in the internal reproductive system of the family Chrysomelidae (Coleoptera). Most of them closely connect with the so-called "material compensation" (compensation of body material: Rensch, 1959; enantiomorphosis: Okada, 1960). Factors conditioning character correlation in the internal reproductive system of the family are divided into two major categories, phylogenetic (or genetic) and non-phylogenetic (or non-genetic). It can be pointed out from the viewpoint of comparative morphology that alteration in body size and body organisation (or form) may have taken an important role in the course of evolution of the system. Tentative categorisation of character correlation in the internal reproductive system of the family is proposed.

PHYLOGENESIS OF THE WESTERN PALEARCTIC SPECIES OF THE GENUS CREPIDODERA CHEVOLAT SENSU FOUDRAS (COLEOPTERA: CHRYSOMELIDAE: ALTICINAE). M. Biondi, Dipartimento di Biologia Animale e dell'Uomo (Zoologia), Università "La Sapienza", 00185 Roma, Italy.

Twenty-five species of the genus *Crepidodera* Chevrolat sensu Foudras in this work are considered. To attempt a reconstruction of their phylogeny, a cladistic analysis has been carried out using parsimony (WAGNER algorithm) and compatibility (CLINCH algorithm) methods.

POPULATION DYNAMICS OF THE TORTOISE BEETLES (COLEOPTERA: CHRYSOMELIDAE: CASSIDINAE) IN SUMATRA. K. Nakamura* (Dept. of Biology, Fac. of Science, Kanazawa Univ., Kanazawa, Japan) and I. Abbas (Dept. of Biology, Fac. of Science, Andalas Univ., Padang, Indonesia).

Populations of the tortoise beetles, *Aspidomorpha miliaris* (AM) and *A. sanctaecrucis* (AS), coexisting on a shrubby morning glory, *Ipomea carnea* (Convolvulaceae), were studied continuously for 27 months (1982-1985) in Padang, Sumatra, by mark-recapture of adults and construction of life tables. Padang lies on the equator, predominated by a tropical humid-equatorial climate: the air temperature was quite constant at 27.0°C and the annual rainfall 4764 mm without a distinct alternation of wet and dry seasons. The minimum and maximum adult numbers estimated by the Jolly method fluctuated from 0-490.2 for AM, and from 0-172.8 for AS. A shortage of food never occurred, but the two species remained at low levels for most of the study period. No clear relationship was detected between the number of beetles of both species and the amount of rainfall. Dissection of collected egg masses showed: The eggs of AM were parasitized by *Tetrastichus* sp. A (Eulophidae) and those of AS by *Cassidocida aspidomorphae* (Tetracampidae). In AM, egg parasitism by the parasitic wasps remained rather stable around 40% throughout the study period, while in AS it fluctuated violently ranging from 0-100%. The seasonal fluctuation in the intensity of egg parasitism again exhibited no simple relationship with the amount of rainfall and density of egg masses.

ON THE PHYLOGENETIC POSITION OF THE BRUCHIDAE WITHIN THE CHRYSOMELOIDEA (COLEOPTERA). M. Schmitt, Albert-Ludwigs-Universität, Institut für Biologie I, D-7800 Freiburg, FRG

The family Bruchidae and five subfamilies of the Chrysomelidae constitute a monophyletic group. This decision is based on their bifid tarsal setae which are found in no other Coleoptera. The chrysomelid subfamilies Donaciinae, Criocerinae and Sagrinae form one monophyletic group (the Crioceriformes), and the Cassidinae and Hispinae make up the Cryptostomes. Within the Bruchidae, the group Urodoninae lacks bifid tarsal setae, and so must be excluded from this taxon. Antennal insertion in the Urodoninae, however, is similar to that of the Curculionoidea, indicating that they belong to this group. Bruchidae sensu stricto are then monophyletic, but their position within the Chrysomeloidea is still open to debate. The monophyly of the aforementioned groups is still discussed and the sister-group relationship of the Bruchidae shown. In addition, a sister-group for the bifid-setae-bearing Chrysomeloidea is suggested.

DIFERENTIAL DISTRIBUTION OF ENZYME ACTIVITY IN THE MID-GUT OF ASPIDOMORPHA MILIARIS F. (COLEOPTERA CHRYSOMELIDAE). K.K. Verma* and R.K. Shrivastava, Department of Zoology, Government Arts and Science College, Durg, M.P., 491001, India.

Digestive activity in extracts from different parts of the mid-gut has been studied. These studies reveal a differential distribution of digestive enzyme activity in different parts of the mid-gut. Proteases are most active in the hepatic caeca and in the endoperitrophic lumen of MS1, while amylase activity is most marked in the ectoperitrophic space of MS1 and in the lumen of MS2. Lipases show maximum activity in MS2.

THOUGHTS ON PAST CLASSIFICATIONS OF THE WEEVILS - HOW A NEW SCHEME MAY BE ATTEMPTED. Guillermo Kuschel, Entomology Division, DSIR, Private Bag, Auckland, New Zealand.

Distinctiveness, not similarity used to be the main criterion to rank taxa in plant and animal classifications. The weevil system did not escape that trend ending up with nearly two dozen families and over a hundred subfamilies. A phylogenetic analysis of Curculionoidea is attempted for the first time based on a selection of characters from an initial data matrix of 200 character states of adults and larvae applied to over 100 major family-groups. The cladistic approach goes a long way towards simplifying the old classification, but leaves relationships of subfamilies within the largest family Curculionidae still unresolved to some extent. As a consequence, the criterion of reciprocal illumination between relationships and biogeography is applied to this family. By demanding a world-wide distribution that would guarantee at least a Cretaceous age for the subfamily status, related groups are merged till world-wide distribution patterns are achieved. The new analysis and scheme recognizes in the superfamily Curculionoidea six families and 30 subfamilies. All the families and 16 out of the total of 30 subfamilies are defined by unique, shared derived character states, the other 14 subfamilies must remain in limbo as to their final status till further work can sort them out cladistically.

THE STRUCTURE OF THE CURCULIONID HEAD AND WEEVIL PHYLOGENY (COLEOPTERA: CURCULIONOIDEA). C.F.C. Lyal, Department of Entomology, British Museum (Natural History), Cromwell Road, London SW7 5BD, England.

The weevil head is much modified from that of a more 'typical' coleopteran as, in the evolution of the rostrum, sclerites and sutures have been lost or have changed their spatial relationships. Parts of the classification of the Curculionoidea, particularly involving the orthocerous families, rely on disputed interpretations of head structures; the homologies of these structures are examined and various phylogenetic hypotheses are considered from a cladistic viewpoint.

SYSTEMATIC POSITION OF THE SCOLYTIDAE AND PLATYPODIDAE (COLEOPTERA). Stephen L. Wood, 332 Life Science Museum, Brigham Young University, Provo, Utah U.S.A. 84602.

Within Curculionoidea, fully pregonal sutures have been found in females of two species of Belidae, but in no other curculionoids. A review of adult and larval characters suggests that Scolytidae and Platypodidae are: (1) very closely related to one another, (2) more closely allied to curculionoids having two separate gonar sutures than to more highly evolved families, and (3) rather remotely allied to Curculionidae.

PHYLOGENETIC VALUE OF IMMATURE STAGES IN CURCULIONOIDEA. H.R. Burke, Department of Entomology, Texas A&M University, College Station, Texas 77843 U.S.A.

Curculionoid larvae and pupae exhibit many characters of taxonomic value but the information provided by these stages has not been widely used in study of the phylogeny of the group. Some subgroups of Curculionoidea, ie. Anthribidae and Scolytinae, have the immatures relatively well known whereas for others such information is incomplete or lacking. A few attempts have been made to incorporate larval characters in classifications and phylogenies of the Curculionoidea but no analysis of these characters has been made throughout the superfamily. Much more collecting and study of immatures critical to the understanding of the phylogeny of the group needs to be conducted before an overall analysis is possible.

External characters of larvae of importance in identifying species and determining phylogenetic relationships include numbers and arrangement of setae, characters of the head capsule, mouthparts and antennae, presence or absence of legs, divisions of abdominal segments and location of the anus. Internal characters of the alimentary canal are also being studied to determine their taxonomic value. Since pupae of curculionoids possess some characters not shared with either larvae or adults they should also be considered in phylogenetic studies.

STRUCTURES RELATED TO OVIPOSITION IN CURCULIONOIDEA. A.T. Howden, Department of Biology, Carleton University, Ottawa, Ontario K1S 5B6, Canada.

Structures of the reproductive system reflecting the method of oviposition are primarily the vagina, coxites, and styli. The length of the vagina is related to the distance the egg is carried from the body. When extremely elongate the vagina is accompanied by pairs of reinforcing baculi and telescopes within the abdomen. Extreme shortening of the vagina is associated with taxa placing eggs in prepared galleries, loose in ground litter, or loose in the soil. Coxites and styli are variously modified for preparing an oviposition site in soil, plant stems, flowers, etc.

The apical margin of tergite 8 of females may also vary according to the method of oviposition. A crenulate, dentate, or serrate margin occurs randomly throughout Curculionoidea, and its use as a rake is suggested for a brentid.

Representative observations illustrate the correlation between morphology and oviposition.

MALE GENITALIA AND THEIR SYSTEMATIC SIGNIFICANCE IN CURCULIONOIDEA-H.R. PAJANI, ZOOLOGY DEPARTMENT, PANJAB UNIVERSITY, CHANDIGARH, INDIA.

The male genitalia in the superfamily Curculionoidea is constituted by the aedeagus and the ring-shaped phallobase, with the former prolonged into a pair of apodemes and the latter extended in a single apodeme. The aedeagus is comprised by the outer hardened exophallus and the invaginated flexible endophallus furnished with a variety of sclerotized structures. The endophallic armature provides the most reliable character for the discrimination of species. The structure of genitalia is also co-related to the taxa of genera, subfamilies and families, although its significance is variable in different groups. The variations relate to the shape of aedeagus, length of aedeagal and phallobasic apodemes and structure of gastral spiculum. The presence or absence of parameral processes on the dorsal aspect of the phallobase also provides useful demarcative features. The male genitalia are thus of great help in the taxonomy of curculionoidea and can be suitably utilized for resolving the continuing controversy on the status of a few families and their component subfamilies and genera. Details of the structure in the 1,500 studied species of Indian Curculionoidea will be presented.

SOME OBSERVATIONS ON THE CLASSIFICATION OF THE SUBFAMILIES OF CURCULIONIDAE. K. Morimoto, Entomological Laboratory, Faculty of Agriculture, Kyushu University, Fukuoka, 812 Japan.

Subfamilies of the Curculionidae are defined principally on 52 characters of the adults and partly on 45 characters of the larvae from the Palearctic and Oriental regions. Scolytidae, Platypodidae and Rhynchophoridae are excluded from Curculionidae as independent families. The characters observed are analysed by the numerical and cladistic methods. The adelognathous subfamilies are redefined on the characters of the mouth organs, metendosternites and genitalia of both sexes. Sitoninae and Pachyrhynchinae are recognized as independent subfamilies from Brachyderinae. Cleoninae are well defined by the position of the labial palpi and short apophyses of the penis. Paepalosomini must be referred to Cleoninae. Cossoninae are quite different from Scolytidae on the head structures, and must be excluded Aphelini and Dryophthorini. Definitions of the other subfamilies are also discussed on the new data.

AN EVOLUTIONARY PERSPECTIVE ON THE DIVERSITY OF CURCULIONIDAE (COLEOPTERA). Robert S. Anderson, Department of Entomology, Texas A & M University, College Station, TX 77843, U.S.A.

The Curculionidae is the largest family of organisms known. This is hypothesized to be due to interaction between 1), use of the rostrum by females in excavation of oviposition sites, and 2), the history of the association of Curculionoidea with plants.

Length of rostrum in most Curculionoidea is greater in females than males. Data on variation in female rostrum length in species of genus *Curculio* in North America shows marked correlation with variation in length of membranous, telescoping ovipositor suggesting the two form a functional complex. Additional data on variation in female rostrum length/body length ratios in *Anthonomus quadrigibbus* gives evidence of selection for disproportionately longer rostrum in specimens ovipositing in larger fruits. All evidence indicates that female Curculionidae possess a functional sclerotized ovipositor, and associated evolutionary benefits, in the form of the rostrum.

Comparison of phylogeny of Curculionoidea with phylogeny of plants shows general correlation; primitive weevils/ primitive plants, advanced weevils (Curculionidae)/angiosperms. This indicates weevil/plant association predated origin of angiosperms such that development of an elongate rostrum may have been the catalyst in an early exploitation of nutrient-rich reproductive structures of ancestors of angiosperms preadapting primitive Curculionoidea to subsequent exploitation of the angiosperms by Curculionidae.

WEEVILS, PREMIERE BIOCONTROL AGENTS (COLEOPTERA: CURCULIONIDAE). C.W. O'Brien, Entomology - Biological Control, Florida A&M University, Tallahassee, Florida 32307.

The value of the use of weevils as biological control agents of weeds is established for their use in both aquatic and terrestrial environments. Examples of plants and their biological control agents are discussed, including the following: *Eichhornia crassipes* Solms, *Neochetina bruchi* Hustache and *N. eichhorniae* Warner; *Salvinia molesta* Mitchell, *Cyrtobagous salviniae* Calder and Sands; *Tribulus terrestris* Linnaeus, *Microlarinus lareynii* (Jacquelin du Val) and *M. lypriformis* (Wollaston); etc. The relatively narrow host acceptability of many weevils, which makes them especially suitable as such agents, is reviewed. The importance of a sound taxonomic approach to the problem is discussed in relation to difficulties involved with sibling species.

SUCCESSIONAL COMMUNITIES OF PLANTS AND WEEVILS. V.K. Brown* and P.S. Hyman, Imperial College (University of London) at Silwood Park, Ascot, Berks. SL5 7PY, U.K.

A secondary succession on sandy soil in southern England is represented by seven experimental sites of known successional age, from the colonisation of bare ground, through permanent pastureland to birch woodland. The development of the sites over a 5 year period is described. Communities of plants and weevils from different aged sites are defined by reciprocal averaging ordination and are characterised by a sequence of dominant species. The species diversity of herbs and weevils is closely related throughout the succession. It is suggested that plant-species composition may be more important than plant structure in solely phytophagous groups of insects. The host-plant associations of weevils are described in terms of generalism-specialism and niche breadth. The occurrence of a higher degree of generalism in weevils in late succession, than predicted in certain models of succession, is explained in terms of Rhoades' and Cates' theories of plant/anti-herbivore chemistry.

AQUATIC ADAPTATIONS OF WEEVILS: SURFACE SWIMMING IN CURCULIONOIDEA. M.G. Morris (UK).

No Abstract

SAND DUNE CURCULIONIDAE (COLEOPTERA) WITH SPECIAL EMPHASIS ON THOSE OF WESTERN NORTH AMERICA. E.L. Sleeper, Department of Biology, California State University, Long Beach, California 90840, U.S.A.

Morphological adaptations for an obligatory existence in a total sand substrate are known to occur in seven subfamilies and 25+ genera. These weevils are distributed over all major continents except Antarctica. In North America all but one species are found west of the 100th meridian. Nearly all forms in North America are associated with self and barchan dunes of existing or ancient seashores. All forms encountered to present are from quartz derived sands with a very high percentage of the particle sizes in the 0.17-0.35 mm range. Particle size is one of the more important parameters in this habitat. It has had a profound effect on the morphological adaptations and driven character convergence in many genera of very distantly related subfamilies. Very similar morphological structures have developed independently several times.

VICARIANCE, PHYLOGENETICS AND PHENETICS IN ASSESSING SPECIES RELATIONSHIPS AND DISTRIBUTIONAL PATTERNS OF SPECIES OF *CYLAS* (COLEOPTERA: CURCULIONOIDEA) G. Wolfe, Department of Entomology, Rutgers University, New Brunswick NJ 08903.

The major thrust of this research involves pest species of *Cylas*. Taxonomic and distributional data indicate that: 1) *Protocylas* is a junior synonym of *Cylas*, 2) there are as many as eight pest species of *Cylas* which are placed in three main pest species groups - *C. formicarius*, *C. brunneus*, and *C. puncticollis*, and 3) maximum pest species diversity occurs in Central Africa.

Phylogenetic and distributional information has shed considerable light on origin of pest species. Current results show that *C. formicarius* is the most plesiotypic member in *Cylas*. Phenetic trees and phylogenetic trees correspond rather closely. It is hypothesized that the common ancestor to *Cylas* existed in Gondwanaland. The separation of India from Africa was the vicariant event that divided the ancestor to the genus; populations isolated on India evolved to *C. formicarius* and all other species are derived from the African isolate. Based on this information it is speculated that *C. formicarius* is not native to the African continent.

SYSTEMATICS AND BIOGEOGRAPHY OF THE SUBFAMILY MICRO CERINAE (COLEOPTERA: CURCULIONIDAE). S. Louw, Department of Entomology, National Museum, P.O. Box 266, 9300, Bloemfontein, South Africa.

The adelognathous curculionid subfamily Microcerinae comprises three genera, viz. Episus Billberg, Microcerus Schoenherr and Gyllenhalia Aurivillius. These ground-living weevils are restricted to subsaharan Africa of the Afrotropical region where an extensive fauna of the group has evolved, mainly in the more arid regions. From an analysis of the phylogeny and zoogeography it is deduced that the group originated in East Africa, has eastern and southern centres of speciation and is closely related to Brachycerinae and Brotheinae. It is established that the plesiomorphic genera Episus and Microcerus have a very wide range in subsaharan Africa and that the apomorphic Gyllenhalia is endemic to southern Africa. On the basis of Gondwanaland continental fragmentation an early Tertiary origin is postulated for the group, whilst the distribution patterns are analysed in relation to palaeoclimatic changes.

Important morphological differences between the final instar larvae of Microcerus and Brachycerus, as well as different larval feeding strategies between these two genera, give rise to questions on the apparent sister-group relationship between Microcerinae and Brachycerinae and the higher taxonomic position of Microcerinae.

SYSTEMATIC POSITION AND COMPOSITION OF THE TRIBE TANYRHYNCHINI (COLEOPTERA: CURCULIONIDAE). R.G. Oberprieler, National Collection of Insects, Private Bag X134, Pretoria 0001, RSA.

The subfamily Tanyrhynchinae has always been regarded as transitional between Adelognatha and Phanerognatha, but has usually been neglected in keys to subfamilies and never intensively studied. Studies of mouthparts and external genitalia, in particular, have shown that most genera of this group are clearly adelognathous, without however fitting into any of the classic adelognathan groups, whereas others are related to phanerognathan Hipporhinus. The type-genus, Tanyrhynchus, is very close to Eremnus and ten allied southern African genera, these together forming an apparently natural group with affinities to Australian Leptopiinae and some southern African Otiorhynchinae, but not to Oriental Cyphicerini as previously assumed. Further studies are needed to identify synapomorphies for this group, which is currently best treated as a tribe Tanyrhynchini of Entiminae, with the family-name Eremninae falling into synonymy with it. The proper delimitation of this group requires urgently needed identification of related monophyletic groups within the Adelognatha, viz. Entiminae.

MIMICRY IN THE ZYGOPINAE (COLEOPTERA: CURCULIONIDAE). H.A. Hespenheide, Department of Biology, University of California, Los Angeles, California 90024, U.S.A.

With a few exceptions, mimicry in beetles is only beginning to be studied and reported. Field collections of the weevil subfamily Zygopinae in Costa Rica and Panama and study of museum specimens show mimicry of several types to be common. Mimicry by Zygopinae is probably Batesian in nature and involves flies, ants, wasps, and other arthropods as models. The occurrence of mimicry is related to geography and climate, microhabitat, and size and behavior of the beetles and their models.

ORDINATIONS, A THIRD (NONPHENETIC) ANALYTICAL ALTERNATIVE IN SYSTEMATICS: THEIR CONTRAST TO CLUSTERING AND CLADISTIC TECHNIQUES. J.T. Sorensen* and R.G. Footitt, Insect Taxonomy Laboratory, California Department of Food and Agriculture, 1220 N Street, Sacramento, California 94271-0001, USA; Biosystematics Research Institute, Agriculture Canada, K.W. Neatby Bldg., Ottawa, Ontario K1A 0C6, Canada.

Basic differences between ordinations versus clustering and cladistic techniques are considered. Although ordinations have historically been considered a "phenetic" technique, they are multidimensional and therefore unlike unidimensional portrayals of variance, such as clustering. Because of this difference, the distances derived from ordination vectors are nonphenetic, since they do not represent measures of "overall similarity" as do clusterings. The vectors indicate partitioned variance, which allows directionality (polarity) as do cladistic techniques.

Two types of ordinations in particular, principal component analysis (PCA) and discriminant function analysis (DFA), also known as discriminant analysis and canonical variate analysis, are discussed in terms of their geometry and its implication and use in systematics.

QUANTITATIVE GENETIC MEASURES OF EVOLUTIONARY DISTANCE: CAN WE ESTIMATE PAST SELECTIVE FORCES? S. Via, Department of Entomology, Comstock Hall, Cornell University, Ithaca, New York 14853, USA.

What is the net force of natural selection required to produce the observed phenotypic divergence between two groups, and on what phenotypic characters has this selection acted? Quantitative genetic models of evolution describe change in the vector of phenotypic means as a function of the genetic variances and covariances of the characters and the direct forces of selection acting on each character. This relationship can be used to estimate the net force of selection required to produce a given magnitude of phenotypic change if the genetic correlations among the characters are known. This talk will concern the assumptions and validity of this method for the estimation of evolutionary distances in phylogenetic analyses; several recent applications will be used as examples.

ORDINATIONS AS INFERENTIAL TOOLS FOR PHYLOGENETIC AND PHENOLOGICAL ASSESSMENTS: THE PRAGMATIC POTENTIAL AND PROBLEMS OF DECIPHERING EVOLUTION IN n-DIMENSIONAL SPACE. J.T. Sorensen, Insect Taxonomy Laboratory, California Department of Food and Agriculture, 1220 N Street, Sacramento, California 94271-0001, USA.

Lande's phenotypic models for generation of net selective pressure gradients are used as inference vehicles for evolutionary interpretation of ordinations. Discriminant function analysis (DFA), in conjunction with cladistic networking algorithms, allows reconstruction of phylogenies at the intrageneric level by employing character correlation and covariance information to determine suites of genetically linked traits. Phylogenetic reconstruction using this system is more in tune with quantitative genetic models of evolution than are systems employing discrete characters which are erroneously assumed to be independent in action.

DFA is also used to demonstrate phenological shifts of morphometric attributes in laboratory colonies maintained for several hundred generations; these shifts reveal differing responses to the "same" selection gradients, and hence differing genetically encoded biological response under "similar" environmental conditions, between sibling species in a species-complex of leafhoppers.

PROBLEMS OF DISCRIMINATION WITHIN PEST APHID SPECIES COMPLEXES, WITH PARTICULAR REGARD TO PERMANENT APOMICTICS. R.L. Blackman, Department of Entomology, British Museum [Natural History], Cromwell Road, London SW7 5BD, UK.

Aphids lend themselves well to multivariate studies, especially when reared as clones so that the phenotypic effects of different environmental factors can be studied on single genotypes. Discrimination between closely related taxa is usually fairly good, but may be confounded by the considerable phenotypic plasticity shown by aphids, which seems to be particularly great in the case of permanently apomictic populations.

INTRAGENERIC EVOLUTIONARY DIVERSITY: DIFFERING PATTERNS OF CHARACTER VARIANCE WITHIN AND BETWEEN GROUPS IN *CINARA* CURTIS APHIDS (HOMOPTERA: APHIDOIDEA: LACHNIDAE). R.G. Footitt, Biosystematics Research Institute, Agriculture Canada, K.W. Neatby Bldg., Ottawa, Ontario K1A 0C6, Canada.

Morphological variation among species of aphids of the genus *Cinara* Curtis, on western North American pines, was characterized using univariate and multivariate analyses. Patterns of morphometric variation were shown to be complex and unique for many of the species. Functional groups of characters exhibited different internal relationships and different degrees of association with the main components of variation. Information on the covariation among the characters allowed for selection of those characters which best discriminated among the species. Knowledge of the variability of characters within and between taxa, at all levels within the hierarchy, would facilitate the development of a sound phylogenetic scheme for the Cinarini.

MULTIVARIATE STUDY OF TEMPORAL VARIATION IN MORPHOLOGY OF A GALL-FORMING APHID. D. Wool* and O. Manheim, Department of Zoology, Tel Aviv University, Ramat Aviv 69978, Israel.

Gall-forming aphids are attractive for morphological studies. The clonal (parthenogenetic) reproduction within galls allows estimation of the relative magnitude of genetic and environmental effects on the variation of each character. In the last 35 years multivariate statistical methods were applied to morphometric characters of two species of *Pemphigus* Hartig, in the USA and, on a much smaller scale, to data from 3 species of the related Fordinae in Israel. These studies were designed to analyze geographical distribution patterns in the morphology of these aphids, and thus focused on the among-locality differences.

Observations on the gall-forming aphid *Aploneura lentisci* (Passerini) in a single locality revealed a seasonal trend of increasing average alate size. The present morphometric analysis deals with the question, of whether this trend is caused by seasonal changes in the size of individuals that mature on different dates within each gall (nongenetic trend), or from differences in emergence times among galls, where galls with larger aphids mature later in the season (such differences may have a genetic component).

USING ORDINATIONS WITH GEOGRAPHIC INFORMATION: SPECIES RESOLUTION IN A PARTIALLY SYMPATRIC COMPLEX OF NEOTROPICAL DRAGONFLIES (ODONATA: LIBELLULIDAE). R.W. Garrison, Los Angeles County Department of Agriculture, 3400 La Madera Avenue, El Monte, California 91732, USA.

Two forms of the large libellulid dragonfly *Tramea binotata* (Rambur) are generally distributed over southern Florida, Mexico, the Antilles, south through southern South America. A red morph, called *Tramea insularis* Hagen, known from allopatric populations in peninsular Florida, the Bahamas and Cuba, is similar to a more wide ranging black morph, known from Mexico, south through South America. The black and red morphs are sympatric only in Puerto Rico, Jamaica and Hispaniola.

Analysis of five mensural characters using principal component analysis (PCA) and discriminant function analysis (DFA) revealed differences in relation to geography, which support treating these two forms as separate species. PCA showed differing patterns of covariance, for the allopatric OTUs in attribute space, suggesting differentiation among character suites for the traits analyzed. In DFA, allopatric populations, used as 'knowns', were employed to assign individuals, as 'unknowns', from the areas of sympatry with an 80% rate of correct classification in relation to color phena.

PRONOTAL SHAPE: A SOURCE OF CONFUSION OR PANACEA IN SYSTEMATIC STUDIES OF OAK INHABITING TREEHOPPERS (HOMOPTERA: MEMBRACIDAE). T.K. Wood, Department of Entomology and Applied Ecology, University of Delaware, Newark, Delaware 19711, USA.

Approximately 80% of North American treehopper fauna are in the tribe Smiliini and the majority of the species are restricted to oaks (*Quercus* Linnaeus). Historically, workers failed to find consistent characters that clearly distinguished genera or species. Without exception they came to rely on the shape of the pronotum for diagnostic features. However, the nature of language made the subtle shape differences difficult, if not impossible, to communicate to others, let alone be of use in developing phylogenetic hypotheses. Species identifications at present rely on a gestalt resulting from visual comparison to line drawings and type specimens. Since generic and species identification is somewhat of an art form this has impeded an understanding of the biogeographic and host utilization patterns of this group. I will examine the use of polynomial equations to define pronotal shape. Specifically I will address their use in describing intraspecific (geographic, hostplant and sexual), interspecific and intergeneric variation in the Smiliini.

ECOMORPHOLOGY OF HOVERFLIES (DIPTERA: SYRPHIDAE). F. Gilbert, Department of Zoology, University of Nottingham, Nottingham NG7 2RD, UK.

The coordinated use of multivariate techniques is used to analyze intra- and interspecific morphology, and then to relate these measures to ecological features. Long term population data are used to examine questions about community ecology.

DESCRIPTION AND SYSTEMATIC ASSIGNMENT OF A LOWER DEVONIAN (LOWER EMISSIAN) INSECT FROM GASPE PENINSULA, QUEBEC, CANADA. C.C. Labandeira*, Dept. Geophysical Sciences, Univ. Chicago, Chicago, Illinois, USA, 60637; B.S. Beall, Dept. Geology, Field Museum of Natural History, Chicago, Illinois, USA, 60605; and F.M. Hueber, Dept. Paleobiology, National Museum of Natural History, Washington, D.C., USA, 20560.

Strata from the south shore of Gaspé Peninsula, Quebec, have yielded a probable microcoryphian. This well-preserved specimen consists of two fragments--a partial head capsule with incomplete mouthparts, and a fragment of coxae-bearing thoracic segments. Ectal cuticle microstructure includes setal punctae, subparallel ridges of acute barbs, and a truss network supporting compound eye ommatidia. Mandibles are monocondylic. Tentorial wall thickenings and muscle insertion bosses may occur. Synapomorphies allying this fossil with the Insecta include (1) a maxillary cardo, (2) paraglossae and glossae, (3) ocelli, and perhaps (4) a labial palpus. Microcoryphian features are the synapomorphies (1) bulbous, dorsally convergent compound eyes, and (2) mandibles with a distal pick and a likely proximal mola.

This insect is macerated from arkosic cobbles in water-lain deposits of the Battery Point Formation, and occurs with the gametophytic phase of *Sciadophyton*. One of three localities of Devonian insects, the Gaspé deposit antedates insect fragments from Gilboa, N.Y. and slightly postdates the Rhynie collembolan.

IMAGE MEMORY STORAGE AND PHYLOGENETIC INFORMATION ON DERMAPTERAN TAXONOMY. SAKAI, Sei-roku, Institute of Biology & Life Sciences, Daito Bunka University, Takasaka, Saitama, Japan, 355

The author carried out Dermapteran integrated taxonomy including numerical, chemo-, physico-, cytotoxic information and published Dermapterorum Catalogus I-XXI (1970-88) involving taxonomic and biogeographical records. The iconographia on Pygidicranidae, Diplatyidae and Anisolabididae including color plates were already published. These atlas of external and genital characters are able to store the video, optical or laser disc. Advances in video, optical, laser disc and video camera are gradually possible to lower cost-application on practical image memory storage on taxonomic characters. The author examined several systems as follows: Victor image print system, Ricoh my print: JP50E, Canon still video system, Arty total design system, Tosfil 3200H and Panafacom C-300. Video tape is more cheaper than laser or optical disc. These disc or tape become to make gradually sharp image. Repeated application of video tape is more practical than disc for analyses. Victor image print system (BRC-300 video camera, color monitor: AV-m150, time lapse video recorder BR-900 and Minolta camera) was most cheapest application for analyses. Also, the author presents a new revised phylogenetic reconstruction of Dermaptera in the family level involving cladistic analyses by Sakai (1984) and Popham (1985). Now, the atlas of Spongiphoridae (Labiidae) and Forficulidae are preparing in the next Dermapterorum Catalogus.

EVOLUTIONARY ECOLOGY OF BLIND PALE CAVE ANIMALS IN HAWAIIAN LAVA TUBES. F.G. Howarth, Entomology Department, B.P. Bishop Museum, PO Box 19000-A, Honolulu, HI 96817, USA

The isolated high Hawaiian islands are young, ranging in maximum age from just over 5 million years (Kauai), 3.7 my (Oahu), 1-2 my (Maui) to less than 1 my (Hawaii); yet a remarkable group of highly modified obligate cave animals have evolved in underground habitats independently on each island, in turn, from native surface species. Surprisingly, most cave species occur on the youngest island (Hawaii) where they must have evolved within the last 700,000 years and where close relatives are often still extant in neighboring surface habitats and where youthful lava tubes abound. On the older islands the cave species often appear to be relicts, without sympatric close relatives. Physiological ecology studies corroborate the theory that cave species are highly specialized to exploit resources within medium-sized subterranean voids, which are well-developed in young basalt flows and other soluble or fractured rock layers.

ADAPTIVE RADIATION AMONG SURFACE AND CAVE DWELLING NEMOBIINE CRICKETS ON THE ISLAND OF HAWAII. F.D. Stone, University of Hawaii at Hilo, Hilo, HI 96720, USA

At least four species of crickets in the genus *Caconemobius* are adapted to life on bare rock habitats on the island of Hawaii. An undescribed halophilic species, dark colored and large-eyed, forages in the wave-splash zone of rocky seacoasts and is the presumed ancestral species. A second dark, big-eyed species, *C. fori* Gurney and Rentz, forages on the surface of new, unvegetated lava flows. Two additional species are cave-adapted, occurring sympatrically in lava tubes and other voids in lava flows, but differing in their adaptations to cave life. *C. varius* Gurney and Rentz, pale brown with reduced eyes, actively avoids light but falls into pitfall traps. The second cave species, undescribed, is smaller, paler, and more gracile than *C. varius*, does not react to light, and is able to avoid pitfall traps. Interestingly, *C. varius*, the less cave adapted of the two species, shows a greater morphological variation over its geographical range. Since both cave species are highly modified for life underground, they must have evolved on Hawaii within its 700,000 year existence.

CHROMOSOME EVOLUTION AND SPECIATION OF THE NANODECTES (ORTHOPTERA: TETIGONIIDAE). N. Ueshima* and D.C.F. Rentz, Department of Biology, Matsusaka University, Kubocho, Matsusaka, Mie, Japan 515 Division of Entomology, CSIRO, Canberra, ACT, Australia 2601.

Nanodectes species are distributed in south Australia. The chromosome number of the species ranges from $2n=15$ to $2n=23$ in the male. Ten types of karyotypes are found in the genus. All the species showed XO sex chromosome mechanism and the X always presented the largest component in the diploid set. In the *N. triodiae* four karyotypes are found.

Chromosome rearrangements, such as centric and tandem fusions, have played an important role of chromosome evolution among inter- and intra-species in the *Nanodectes*. The probable pathways of chromosome evolution and speciation are discussed.

A DISCUSSION OF THE PHYLOGENETIC RELATIONSHIPS AMONG THE GENERA OF THE PARNASSIINAE (LEPIDOPTERA: PAPILIONIDAE): ARE THE PARNASSIINAE A MONOPHYLETIC GROUP? C.L. Häuser, Zoologisches Institut, Albert-Ludwigs-Universität, Albertstr. 21a, D-7800 Freiburg/Br., West Germany.

The Parnassiinae are one of the three currently recognized subfamilies of the Papilionidae and contain about 55 species. Under the assumption that the Parnassiinae form a monophyletic group, the phylogenetic relationships among the eight genera (*Parnassius*, *Archon*, *Hyperbaena*, *Allan-castria*, *Zerynthia*, *Sericanus*, *Bhutanitis*, and *Luehdorffia*) are discussed based on a study of mainly morphological characters, and the results are compared with existing cladograms from the literature. A few selected characters are illustrated with their outgroup comparisons to establish the polarity of the character states. The importance of using several different outgroups when the sister group is not known is noted. It is also discussed that whereas the Parnassiinae share a number of diagnostic characters, it is not certain that any of these provide a synapomorphy for this group.

GENETICS, BEHAVIOR, BIOCHEMISTRY, BIOGEOGRAPHY AND SYSTEMATICS: POLYTHETIC NUMERICAL PHYLOGENIES OF THE ITHOMIINAE AND PAPILIONIDAE (LEPIDOPTERA). Keith S. Brown Jr., Departamento de Zoologia, Instituto de Biologia, UNICAMP, C.P. 6109, Campinas, São Paulo, Brazil 13.081

The combination in a single matrix of carefully polarized characters derived from all stages and aspects of the phenotype of a holometabolous insect may lead to a balanced view of the evolutionary relationships between species, genera and tribes. Analysis of such matrices and ordination of taxa phenetic (UPGMA) and phylogenetic (Wagner 78, PAUP) algorithms gives strongly convergent results, for the 52 genera of Ithomiinae (represented by one or more species, whose early stages are known; 76 characters, many with multiple states) and for about 80 representative species of American Papilionidae. When characters derived from egg, larval and pupal morphology and anatomy, biochemistry, behavior and chromosomes are included, the relationships in both groups are shown to be different from those inferred from adult morphology only, or from any other isolated stage or aspect of the phenotype. The species groupings suggested in the Papilionidae often form widely distributed "biogeographical species" probably equivalent to evolutionary groupings, since their allopatric or parapatric components are often found interbreeding or intergrading at some (but rarely all) points of their contact - often in contrast to well-differentiated morphological characters and sterility of experimental hybrids.

A PRELIMINARY APPROACH TO THE BIOGEOGRAPHY OF THE PHILIPPINES BASED ON BUTTERFLIES (LEPIDOPTERA: PAPILIONOIDEA). T. Racheli* and M. Biondi, Dipartimento di Biologia Animale e dell'Uomo (Zoologia), Università "La Sapienza", Viale dell'Università, 32, 00185 Rome, Italy.

The Papilionoidea from the Philippines and Palawan were studied with different statistical methods to show the present day distribution and faunistic similarities. The results can be summarized as follows: a) Palawan is significantly different from the Philippines whilst the similarity with Borneo and Malaysia is unmistakable; b) the high percentage of the Philippine endemic taxa and the low faunistic similarity with the surrounding areas of Malaysia, Borneo and Taiwan, prove that the butterflies of Philippines are well characterized; c) the total number of species on each island is significantly correlated to the island area and less influenced by the distance from Borneo; d) the total number of the endemic taxa on each island is highly correlated to the island area; e) the total number of species and endemic taxa of each family within the Papilionoidea on each island depend, other than the island area, on its altitude and distance from Borneo, according to the ecological requirements of the taxon.

A CLADISTIC ANALYSIS OF A MONOPHYLETIC GROUP OF EPIPASCHIINE GENERA (LEPIDOPTERA: PYRALIDAE) FOUND IN THE WESTERN HEMISPHERE. M. Alma Solis, Maryland Center for Systematic Entomology, Dept. of Entomology, University of Maryland, College Park, Maryland 20742 USA

The Epipaschiinae are a subfamily in one of the largest lepidopteran families, the Pyralidae. The subfamily is composed of approximately 500 species worldwide and is distributed in tropical and temperate areas. Genitalia characters define a monophyletic group of 300 species in the Western Hemisphere.

This investigation establishes or disproves the monophyly of included genera, redefining these where necessary, and estimates the relationship among genera. Wing and genitalia characters are used in conjunction with secondary sexual characters of the head. The maxillary and labial palpi and antennae have been highly modified presumably for pheromonal intraspecific interactions.

MORPHOLOGY AND FEMALE CALLING PHEROMONES IN NEW ZEALAND "ORCHARD LEAF-ROLLER" CLASSIFICATION (LEPIDOPTERA: TORTRICIDAE) J.S. Dugdale, Entomology Division, DSIR, Auckland, New Zealand.

Combined pheromonal and morphological studies on the endemic primary pest leafrollers in export fruit orchards in New Zealand now reveals 1) each former "species" consists of several, non-cross attractive (and in males, structurally distinguishable) entities, 2) the two former genera - *Ctenopseustis* Meyrick and *Planotortrix* Dugdale together consist of four definable entities, 3) many of the "polarities" assigned by Horak (1984) to tortricine character-states are supported, 4) practical diagnoses for distinguishing males of orchard infesting species have been developed and are now in use for evaluating lure catches in monitoring and mating disruption trials, and will shortly be available to orchardists.

CONTRIBUTIONS TO THE TAXONOMY OF CHINESE ENNOMINAE: THE GENERA *SPILOPERA* WARREN AND *LEPTOMIZA* WARREN (LEPIDOPTERA, GEOMETRIDAE). D. Stünig, Zool. Research Institute & Museum Alexander Koenig, D-53 Bonn 1, FRG.

Studies on the genitalia structures of the palaearctic species currently included in the genus *Spiopera* revealed, that this taxonomic treatment is based on superficial similarity only. In fact, 5 (of 6) species cannot be considered congeneric with the type-species *S. debilis* (BUTLER). Three species (*gracilis*, *umbra*, *serrulata*) belong to the genus *Pareclipsis* WARREN, incorrectly treated as a synonym of *Spiopera*. *S. roseimarginaria* LEECH is a close relative of *Leptomiza crenularia* LEECH which does not belong to this genus, either. For the reception of these two species a new genus has to be described. The last species, *S. crenularia* LEECH, is congeneric with a group of habitually and morphologically similar species, currently included in *Leptomiza*. For this group the genus-name *Pristopera* must be restored (type-species: *P. hepaticata* SWINHOE). Recently a second true *Spiopera*-species has been described: *S. chui* STÜNIG from C. and W. China.

SYSTEMATICS OF SOME INDIAN OPHIDERINAE (LEPIDOPTERA: NOCTUIDAE). H.S. ROSE* and A. SRIVASTAVA, DEPARTMENT OF ZOOLOGY, PUNJABI UNIVERSITY, PATIALA -147 002, PUNJAB: INDIA.

The subfamily Ophiderinae pertaining to the family Noctuidae of Order Lepidoptera has immense agricultural importance. Various species belonging to the genera *Othreis*, *Platyja*, *Rhytia*, *Oraesia*, *Ischyja*, *Eudocima*, *Anomis* and *Calyptra* feed specifically on a variety of fruits. In spite of having enormous economic significance, the systematics of Indian Ophiderinae, as such, like many other zoogeographic localities has never been reviewed and revised in the light of the examination of their reproductive organs, in particular besides other morphological characteristics in general during the last eight decades or so. The placement of many genus-complexes under appropriate subfamilies (18 approx) of the family Noctuidae is a subject of vital scientific/phylogenetic interest now, and the higher classification of the group is in fluid state even till to-day. In order to achieve some of these objectives, detailed morphosystematic studies have been undertaken on about one hundred biological species referable to sixty genera of Ophiderinae.

WING VENATION OF PRIMITIVE DIPTERA AND MECOPTERA
George W. Byers, Department of Entomology, University of Kansas, Lawrence, Kansas 66045, USA.

Attention was focussed on the hypothesis that the medial vein (M) in Diptera is never more than three-branched, M_4 being absent. Diptera probably evolved from ancestors closely resembling certain Mecoptera (e.g., Nannochoristidae). Wing venation in Mecoptera is much like the generalized pattern for insects proposed by Comstock. In Mecoptera, vein M characteristically has four branches, and the anterior cubitus (Cu_1) is never branched. Primitive Diptera appear to have nearly equivalent venation, but the posterior cubitus is probably not present. Identity of branches of veins in Tipulidae and Tanyderidae was examined through sequential relationships of veins, by growth of tracheae into the veins of pupae, and by relative elevation or depression of veins with respect to the general plane of the wing. It appears that in the lower Diptera, at least, M is four-branched and Cu_1 is unbranched.

MORPHOLOGICAL AND GENETIC CHARACTERIZATION OF THE AEDES (OCHLEROTATUS) COMMUNIS COMPLEX (DIPTERA: CULICIDAE). R.A. Brust* and L.E. Munstermann, Department of Entomology, University of Manitoba, Winnipeg, Manitoba, Canada R3T 2N2 and Department of Biology, University of Notre Dame, Notre Dame, IN., U.S.A. 46556.

The Aedes communis complex comprises three currently recognized species, A. communis, A. churchillensis and A. nevadensis. Morphological, genetic and biological characters separate these species in North America. A fourth species in this complex occurs in the Lake Tahoe region of California, U.S.A., and may be separated morphologically and genetically, by electrophoretic methods, from the other members. Larvae of this species may be distinguished from A. communis and A. nevadensis by the number of comb scales, and the adults may be distinguished by the shape of the tarsal claws. The low heterozygosity in several montane collections, and especially in collections from Lake Tahoe, CA., (<5%), indicates a high degree of isolation, and suggests there may be relict populations of the A. communis group. Aedes churchillensis is more widespread in North America than earlier reported. It is common in eastern Canada, and in east central U.S.A.

MAKING SENSE OF SWARMS. G. Gibson. Department of Entomology, London School of Hygiene & Tropical Medicine, Keppel St., London WC1E 7HT.

Although it is generally agreed that mosquito swarms are a form of mating assembly, most studies have been descriptive and anecdotal, and no clear understanding has emerged of why insects swarm. A new idea will be presented which may help to explain and analyse swarming behaviour.

A common characteristic of species which swarm is the tendency for extreme fluctuations in population densities. At low densities, swarming is a mechanism by which males and females aggregate, and thereby presumably has a role in optimizing mating success. Under the most extreme low density conditions, a 'swarm' may consist of a single male. However, if the population subsequently 'blooms', the likelihood of males and females meeting outside of, or on their way toward swarms probably increases. Males may nonetheless continue to join swarms in their thousands because of their genetic behavioural legacy from previous generations.

In this framework of understanding, the main function of swarming operates in low density conditions, when swarms are inconspicuous and difficult to study. The conspicuous swarms found during periods of high population density are regarded in this view as vestigial or relict behaviour, as most mating probably takes place elsewhere - at least until the population crashes again.

A CHROMOSOME PHYLOGENY OF ELEVEN MEMBERS OF THE SIMULIUM METALLICUM SPECIES COMPLEX (DIPTERA: SIMULIIDAE) IN LATIN AMERICA. Jan Conn, Instituto de Zoología Tropical, Universidad Central de Venezuela, Apartado 47058, Caracas 1041, Venezuela.

Eleven members of the S. metallicum species complex from Central and South America are described using the polytene chromosome banding pattern of S. metallicum A (Guatemala, Mexico) as a standard. The members are B (Guatemala, Mexico), C (Colombia), D and E (Venezuela), F (Panama), G (Costa Rica), H (Mexico, Guatemala, Panama, Colombia?), I (Mexico, Guatemala), and J and K (Panama).

A cytophylogeny separates the members into 3 lineages. H, I, J, and K form one lineage, separated from the standard by 8 rearrangement steps. D and E form a second lineage on the basis of 6 fixed inversions in common. Three floating inversions characterize the common progenitor of C and G, which form a third lineage. B and F each arose independently from the standard.

ELECTROPHORETIC EXAMINATION OF MIDGE LARVAE FROM THREE PHENOTYPICALLY DISTINCT ASTEROMYIA (DIPTERA: CECIDOMYIIDAE) GALLS. Cathryn L. Crego*, Arthur E. Weis, Neil O. Polans, Carolyn K. Bretz, Department of Biological Sciences, Northern Illinois University, DeKalb, IL 60115.

Morphological data are presented which show three phenotypically distinct gall morphs are produced by what was previously thought to be a single gallmaker, Asteromyia carbonifera. Gel electrophoresis was utilized to determine if the gall variants were produced by a single polymorphic species or whether each variant was produced by a distinct race or species of gallmaker. Electrophoretic data supports the hypothesis that the three gall morphs are produced by three different species of gallmakers. Gene frequency data suggests very limited gene flow among the adults of the three morphs. Models of sympatric and allopatric speciation are considered.

THE RELATED CONNECTIONS OF THE LOWER BRACHYCERA. N.P. Krivosheina, Institute of the Evolutionary Animal Morphology and Ecology, Academy of Sciences, Moscow 117071, Leninsky prospect 33, USSR.

There exist several points of view on related connections among Brachycera - Orthorrhapha (Hennig, 1967; Rohdendorf, 1977; Nagatomi, 1977; Krivosheina, 1982). The borders of the families are drawn not clear because of the existence of the number of groups with disputable systematic position (Anacanthaspis, Nematoceroopsis, Arthroceras, Bolbomyia). This is the result of the one-sided approach with the using of few imaginal signs. The using of immature stages helped to find places of the genera Arthroceras (Krivosheina, 1969) Dialysis (Webb, Losowsky, 1983). The analysis of the whole complex of signs permits to tell about the two main directions of development of the lower Brachycera. One of them is Xylomyidae, Stratiomyidae, Rhagionidae, Glutopidae, Tabanidae, the second is Xylophagidae, Coenomyiidae, Mydidae, Asilidae, Therevidae. The resemblance of Xylomyidae and Rhagionidae with Xylophagidae and Coenomyiidae noticed by many authors, is connected with the existence in these groups more clearly expressed plesiomorphic characters.

TESTING A PHYLOGENETIC HYPOTHESIS: NEW SPECIES OF GYMNOPHORA (DIPTERA: PHORIDAE) FROM JAPAN AND NEPAL. B.V.Brown, Department of Entomology, University of Alberta, Edmonton, Alberta, Canada T6G 2E3.

A previously constructed phylogeny of Gymnophora is tested with several new species from Japan and Nepal. New species support the recognition of the G. nigripennis, G. integralis and G. subarcuata groups and help resolve the problematic G. carina group. The phylogeny and biogeography of the world species of Gymnophora is discussed.

PHYLOGENY AND HIGHER CLASSIFICATION OF TEPHRTID FRUIT FLIES (DIPTERA). A. Freidberg, Department of Zoology, The George S. Wise Faculty of Life Sciences, Tel Aviv 69978, Israel.

The classification of the Tephritidae is still unsettled and no phylogenetic tree has as yet been proposed for the higher categories of this family. Based on morphological and biological evidence, it is suggested that the evolution of the family has resulted in two main sublineages: that around the mainly frugivorous trypetines and dacines, containing species closer in morphology to the outgroup of the family (Platystomatidae, Otitidae, etc.), and that around the tephritines, containing almost all species of the family with host specificity within the Asteraceae (=Compositae). There are two monophyletic groups, the myopitines and aciurines, that do not fit well into either of the above-mentioned sublineages. Their status, as well as the status of some problematic genera, is discussed. The possible relationships between various tribes are also discussed.

BIOLOGY OF RIVELLIA SPP. (DIPTERA: PLATYSTOMATIDAE), CONSUMERS OF THE NITROGEN FIXING ROOT NODULES OF LEGUMES. B. A. Foote, Department of Biological Sciences, Kent State University, Kent, OH 44242.

Larvae of 12 of the 31 Nearctic species of Rivellia are known to attack root nodules of native legumes. One of the best studied relationships is that of R. melligins and black locust. Adults emerge in northern Ohio in late May, courtship and mating occur on the host plant, and eggs are deposited in soil. Larvae invade root nodules, completely destroying the nitrogen-fixing capability of the nodule. Up to 6 nodules are required for the larval development.

Laboratory rearings indicate that host selection is performed solely by adult females. Larvae are indifferent as to kind of nodule provided and readily attack nodules of such agriculturally important legumes as soybean, alfalfa, clovers, beans, and peas. One species has already shifted from its native host to soybean in the southeastern states, and it is predicted that additional host shifts to introduced, economically important legume species will occur.

NEOTROPICAL ELEMENTS IN THE NEARCTIC FAUNA OF SYRPHIDAE (DIPTERA). J.R. Vockeroth, Biosystematics Research Centre, Agriculture Canada, Ottawa, Canada, K1A 0C6.

The native Nearctic Syrphidae consist of about 870 species referred to 100 genera and subgenera. Of these 100, 28 occur only in the New World; 16 of these are in both the Nearctic and Neotropical Regions. Twelve of the 16 are primarily Neotropical; they have over 1000 species south of the United States and 99 north of Mexico, with 11 of these occurring in southern Canada. The distribution, relationships and possible history of these groups, plus one additional circumtropical group, are discussed. A possible reason for the great diversity shown by some of these groups is outlined.

CHROMOSOMES OF THE FRUIT FLY CARPOMYIA VESUVIANA COSTA (TRYPETIDAE:DIPTERA). D.Kaul* and S.Bhatnagar, Department of Zoology, University of Allahabad, Allahabad-211 002, India.

The fly Carpomyia vesuviana Costa damages the fruit of ber (Zizyphus jujuba and Z. nummularia) in India. C. vesuviana has a diploid chromosome number $2n=10$. The karyotype as studied in the neuroganglial mitosis from third instar larvae consists of two pairs of very large metacentric, two pairs of medium sized telocentric and a pair of small dot-like chromosomes. No heteromorphic pair of chromosomes could be observed in the neuroganglial tissue from a large number of larvae examined and hence the sex chromosomes could not be determined. The small pair of dots which is totally C-band positive and does not show somatic pairing even in interphase or prophase of mitosis may constitute the sex pair. Large and conspicuous C-bands are present at the centromeric ends of the two medium sized telocentrics. This karyotype differs significantly from the karyotypes of the closely related genera Rhagoletis and Zonosemata. On cytological evidence Carpomyia should be maintained as a separate genus.

CURRENT SYSTEMATIC RESEARCH ON NEW WORLD RACHISPODA (DIPTERA: SPHAEROCERIDAE): ZOOGEOGRAPHIC IMPLICATIONS FOR THE FAMILY. T.A. Wheeler, Dept. of Environmental Biology, University of Guelph, Guelph, Ontario, Canada N1G 2W1.

The cosmopolitan subgenus Leptocera (Rachispoda) comprises 94 species. Although 44 species are recognised in the New World, there appear to be many undescribed species. In this paper, the taxonomy of New World Rachispoda is reviewed, and current systematic research summarised.

Systematic revision of Rachispoda is necessary for two reasons. Firstly, specimens of Rachispoda constitute the bulk of most museum collections of sphaerocerids. As a result, adequate keys and descriptions are required for species determination. Secondly, zoogeographic analysis of Rachispoda may be useful in inferences on the historical biogeography of the Limosininae (Sphaeroceridae).

Previous analyses of limosinine genera have revealed a number of patterns in the distribution of sister groups. Four of these patterns are discussed: East Nearctic/West Palearctic relationships; Northwest Nearctic/East Palearctic relationships; East/West disjunctions in the Nearctic; and Neotropical/Nearctic patterns. Zoogeographic analysis of a widespread, speciose group like Rachispoda should reinforce distributional patterns seen in other genera, and help to fill gaps in the historical biogeography of the Limosininae.

EXPLICIT CHARACTER WEIGHTING IN PHYLOGENETIC SYSTEMATICS.
S.A. Marshall, Department of Environmental Biology,
University of Guelph, Guelph, Ontario, Canada N1G 2W1.

The inevitability of character weighting in phylogenetic systematics is not a new observation, nor should it be a controversial one. The mere selection of a finite set of characters to be used in phylogenetic analysis comprises weighting, since characters not selected are given a weight of zero. Furthermore, practicing systematists usually spend a great deal of time considering the characters they use in analyzing their study group, and would for the most part agree that some putative synapomorphies are "better" than others.

In this talk I hope to argue that 1) the recognition of "better" (high weight) synapomorphies is an important aspect of phylogenetic analysis; 2) the construction of a preliminary, partially resolved cladogram based on high weight characters is sometimes a useful step in phylogenetic analysis; 3) most significantly, the explicit recognition of character weights on published cladograms greatly enhances the value of those cladograms by clearly indicating the confidence with which the systematist is presenting each clade.

The above points will be illustrated using the author's revisionary work in the Sphaeroceridae, a poorly known family of acalyptrate Diptera.

L'ÉTUDE DES DIPTÈRES PARASITOÏDES ET LA PRÉSENCE DE LA TAXINOMIE SUR LA NOMENCLATURE. C. Dupuis, Entomologie, Muséum, 75005 Paris, France.

Le programme de ce Congrès montre que les recherches modernes sur les parasitoïdes intéressent plus souvent les Hyménoptères que les Diptères. Néanmoins, des recherches originales sur les oeufs, les larves, les spécificités parasitaires, le mariage des sexes, les comportements, etc., chez les Phasiinae (C. Dupuis) ou dans le genre Blaesoxipha (J. & J. Léonide), prouvent que des avancées biotaxinomiques significatives sont possibles chez les Diptères parasitoïdes comme ailleurs. Les pionniers de ces avancées n'ont guère encore trouvé d'imitateurs parmi trop de Diptéristes qui subordonnent toujours, comme au 19e siècle, la taxinomie à la nomenclature. Pour rompre avec cette routine, il faut, d'abord, à l'aide d'abondants matériaux vivants, définir les espèces sur des bases généalogiques factuelles (par exemple, celles invoquées ci-dessus) et, ensuite seulement, se soucier, sur de rares matériaux de musée, de les nommer de manière typologique formelle.

PATTERNS OF GEOGRAPHIC DISTRIBUTION AND DISPERSAL AMONG NORTH AMERICAN CLIFF SWALLOW FLEAS (SIPHONAPTERA: CERATOPHYLLIDAE). T.D. Galloway, Department of Entomology, University of Manitoba, Winnipeg, Manitoba, Canada R3T 2N2.

There are currently five recognized species of fleas associated with the cliff swallow, Hirundo pyrrohnota: Ceratophyllus arcuegens Holland, C. calderwoodi Holland, C. celsus Jordan, C. petrochelidoni Wagner, and C. scopulorum Holland. Reproduction in all five species is restricted to the breeding season of the host, which constructs its nests on vertical surfaces which are sheltered from wind and rain. Historically, these fleas were probably limited to areas where suitable nest substrate was available for the host. In recent times, by construction of bridges and buildings along waterways, man has allowed the cliff swallow to expand its range and to increase in abundance across North America into areas previously unavailable. The ranges of the flea associates have expanded coincidentally, with that of the host, and some are now broadly sympatric, notably through southern Manitoba, Saskatchewan and Alberta.

BIOGEOGRAPHY AND EVOLUTION OF BEETLES OF THE GALAPAGOS ARCHIPELAGO, ECUADOR; A PRELIMINARY ANALYSIS. Stewart B. Peck* and Jarmila Peck, Department of Biology and Earth Sciences, Carleton University, Ottawa, Canada, K1S 5B6.

The Galapagos Archipelago is a model system for estimating the dynamics of biotic dispersal to and differentiation on oceanic islands. The fauna is still poorly known but at least 51 beetle families, 199 genera, and 336 species are present. The islands, 800-1000 km west of the coast of Ecuador, have been available for terrestrial colonization for 3 million years. Few genera (9) are endemic and may represent early colonizations in seven families: Carabidae (1), Staphylinidae (2), Hydrophilidae (1), Scarabaeidae (1), Nitidulidae (1), Melyridae (1), and Tenebrionidae (2). Species swarms occur in often flightless genera: *Pterostichus* (11), *Physorinus* (7), *Stomion* (9), *Ammophorus* (12), *Pedoneces* (16), *Pantomorus* (6), and *Neopentarthrum* (6). About 23% of the species are native and 74% are endemic to one or more islands. The fauna of 326 naturally occurring species is estimated to have originated from at least 260 successful ancestral colonizations, a rate of one successful colonization every 11,500 years. Most of the colonists passively reached the islands through the air or by rafting from Central South America. Speciation has been suppressed by (1) lack of strong ecological diversity; (2) closeness to mainland source areas; and (3) geological recentness.

FOVEAE OF PSELAPHIDAE - THEIR PRIMITIVE PATTERN, USEFULNESS IN SYSTEMATICS, AND PROBABLE FUNCTION (COLEOPTERA). D.S. Chandler, Department of Entomology, University of New Hampshire, Durham, NH, USA 03824

Only recently has it been recognized that foveal patterns of the Pselaphidae are useful in characterizing genera and in indicating relationships within the family. Foveae are cuticular invaginations containing a single, presumably sensory, seta. The greatest number of foveae are found in the Faronini (Faroninae), a tribe considered to be the most primitive by earlier authors based on other criteria. The evolutionary trend is toward foveal loss, and foveal pairs are variably or convergently lost within several pselaphid lineages. The primitive foveal system for the family is derived from the Faronini, the foveae are labeled, and the system is applied to members of several tribes in the other five subfamilies. The foveal system of Pselaphidae is a unique set of derived features that indicate the monophyly of the group.

PSELAPHIDAE AND STAPHYLINIDAE (COLEOPTERA): THE "MISSING LINK" DISCOVERED? A. F. Newton, Jr.* and M. K. Thayer, Division of Insects, Field Museum of Natural History, Chicago, Illinois 60605, U.S.A.

The large family Pselaphidae has long been considered closely related to, and probably derived from, part or all of the even larger family Staphylinidae, but there has been no agreement on the exact nature of this relationship. This is due in large part to the rather specialized, "canalized" structure of pselaphid adults and larvae, which has hindered the recognition of their sister group within Staphylinidae. At least four potential sister groups for pselaphids have been suggested: Staphylinidae as a whole; the "Stenine Group" of subfamilies; one or more of the "Omaliine Group" of subfamilies; and the family Scydmaenidae, itself a probable staphylinid derivative.

A newly discovered genus and species from Malaysia may resolve this controversy. This genus has the appearance and many, but not all, of the detected synapomorphies of Pselaphidae, and is evidently the sister group of pselaphids. The genus also has derived features (defensive glands of Sternum VIII, etc.) that clearly place it within the "Proteinine Subgroup" of the "Omaliine Group" of Staphylinidae. Phylogenetic relationships among the members of this group, and implications for formal classification, are discussed in detail.

THE PROMISE OF LARVAL CHAETOTAXY FOR PHYLOGENETIC STUDIES OF OMALIINAE (COLEOPTERA: STAPHYLINIDAE). M. K. Thayer, Field Museum of Natural History, Chicago, Illinois 60605, U.S.A.

Larvae have begun, in recent decades, to receive some of the attention they deserve for systematic research on Staphylinidae, in both descriptive and phylogenetic studies. Most work on staphylinid larvae, however, has not made use of chaetotaxy aside from recognition of different kinds of modified setae in certain groups.

Study of representative larvae of Omaliinae and the related Proteininae shows their setae and campaniform sensilla to be relatively stable among individuals and, for the most part, to conform to the system of chaetotaxic nomenclature proposed by Ashe and Watrous for the subfamily Aleocharinae. Survey of chaetotaxic variation in 19 genera of Omaliinae and 4 genera of Proteininae and comparison of these with the more distantly related Aleocharinae suggest that larval chaetotaxy, and other larval structural features, will provide useful phylogenetic characters at many taxonomic levels in Omaliinae and related groups. For example, chaetotaxy of newly discovered larvae of Coryphini supports monophyly of the tribe as proposed on the basis of adult features. The full extent of chaetotaxic homology within Staphylinidae and other Staphylinoidae merits further investigation.

EVOLUTION OF THE ANT-LIKE PETIOLE AMONG THE STAPHYLINID BEETLES (DORYLOMIMINI) LIVING WITH THE NEW WORLD ARMY ANTS (ECITONINI). Herbert R. Jacobson* and David H. Kistner, Dept. of Biol. Sci., California State University, Chico, CA 95926.

Dorylomimini are found throughout the world in the nests of army ants. They are characterized by an myrmecoid appearance including an ant-like abdominal petiole and "gaster". Work with the New World Dorylomimini leads us to conclude that the petiole evolved independently a number of times. In the New World genera, the petiole is formed by the 2nd abdominal tergite and part of the 3rd segment. The posterior portion of the 3rd segment forms part of the "gaster". Despite the similarities, the distribution of other characters suggests that the genera evolved along 3 independent lines, one sister group with each of the 3 major army ant genera. Certain differences in the petioles, support the conclusion that they also evolved independently in each line. Repeated development of the petiole may be an allometric response to the elongation of the head and thorax which in itself may result from selection for mimicry and/or an adaptation to the hosts' subterranean habits.

CHARACTERISTICS OF STAPHYLINIDAE (COLEOPTERA) FAUNA IN THE SOUTH OF THE SOVIET FAR EAST. L.D. Filatova, Pacific Institute of Geography, Far-Eastern Branch, USSR Academy of Sciences, 690032 Vladivostok, USSR.

In the south of the Soviet Far East 341 Staphylinidae species belonging to 9 subfamilies, 20 tribes and 94 genera were registered. In species composition the subfamilies are subdivided into Staphylininae (110 sp.), Oxytelinae (57), Tachyporinae (54), Aleocharinae (47), Steninae (32), Paederinae (30), Oxyporinae (8), Micropeplinae (2), and Euaesthetinae (1). Staphylinidae fauna is heterogeneous in its origin. It is made of many zoogeographical elements characterized by different types of areas. According to the types of the areas, the fauna is divided into three main complexes, namely: boreal, palaearchaeartic and steppe one. The boreal complex combines species of holarctic type of areas (39 sp.), transpalaearctic (57) and angarian (25). The palaearchaeartic complex consists of species of the manchu type of area (55), japanese-manchu (45), wide palaearchaeartic (3) and endemics (45). The steppe complex contains species with all-steppe type of area (3).

BIOGEOGRAPHICAL ALLUSIONS AND ILLUSIONS PORTRAYED BY THE AREODINA (COLEOPTERA: SCARABAEIDAE: RUTELINAE). Mary Liz Jameson, Systematics Research Collections, W436 Nebraska Hall, University of Nebraska, Lincoln, Nebraska 68588-0514, U.S.A.

The Areodina is comprised of nine disjunctly distributed genera that occur in eastern Brazil, central Africa, and throughout much of the United States and Mexico. The subtribe is absent from Honduras to Colombia. Taxa in eastern Brazil and central Africa are probably relictual and suggest a Gondwanan origin, whereas the origin of the disjunct Mexican-American taxa is not as readily explainable. If these taxa are truly monophyletic, what can then account for the gap between the Mexican-American taxa and the eastern Brazilian taxa? Hypotheses for vicariance and dispersal events are discussed as well as a suggestion for a polyphyletic origin of the Areodina. The occurrence of the Areodina in North America remains largely problematical.

BIOGEOGRAPHY OF THE FLIGHTLESS CONNATA-GROUP OF DIPLLOTAXIS IN THE MOUNTAINS OF SOUTHEAST ARIZONA. (COLEOPTERA: SCARABAEIDAE). Scott McCleve, 2210 13th Street, Douglas, Arizona, U.S.A., 85607.

Investigations over more than a decade have shown that the flightless, mountain-isolated connata-group of Dipllotaxis in southeast Arizona is much larger and more complex than the 3 species indicated in the last revision (Vaurie, 1960). To date, 9 populations have been found in 8 separate mountain ranges in the drainage of the Gila River, and more populations are suspected.

All 9 populations are separable from each other on morphological characters. A new technique, involving use of the complex molar surfaces of the mandibles, possibly never before used in scarabs, is described. Reasons are given for tentatively considering all 9 populations as full species. The breakdown of the group into 3 subgroups of respectively 4, 3, and 2 species is described. Geographical, altitudinal, food plant, and habitat characteristics are given for all 3 subgroups.

An hypothesis is given for 1) origin of the group in northern Mexico, 2) subsequent dispersal of the ancestral stock along riparian corridors of the Gila River system during the Pleistocene and 3) eventual isolation in separate mountain ranges that is evident today. Inferences regarding major speciation events are also given.

EUCHIRINAE (COLEOPTERA: SCARABAEIDAE) OF THE WORLD: DISTRIBUTION AND TAXONOMY. R.M. Young, University of Nebraska State Museum, W436 Nebraska Hall, Lincoln, NE 68588-0514, U.S.A.

Euchirinae, a subfamily of tree-hole Scarabaeidae, is comprehensively reviewed for the first time. The genera Euchirus Burmeister (two species), Cheirotonus Hope (eight species) and Propomacrus Newman (two species) are recognized and defined. In insular and continental Asia species are found between ca. 5S (Sulawesi) and 32N latitude (Nanjing, China). Propomacrus bimacronatus (Pallas), once suggested as being extinct, is recorded from Cyprus, Greece, Iran, Israel, Syria, Turkey and Yugoslavia. Distributional data are correlated with orographic features and precipitation patterns throughout Asia, India and the Near East.

Occurrence of the subfamily is wholly associated with heavily forested montane highlands which furnish the old-growth brood trees and plant exudates required for survival of immatures and adults respectively. Brood tree biology is discussed.

LARVAL STAGES AND BIOLOGY OF EASTERN U.S. EPITRAGINI (COLEOPTERA: TENEBRIONIDAE), WITH THE DISCOVERY OF A NEW FORM OF PUPAL "GIN-TRAP". Warren E. Steiner, Jr., Department of Entomology, NHB-169, Smithsonian Institution, Washington, D. C., 20560, USA.

Adult and immature stages of Bothrotes canaliculatus arundinis (LeC.), Epitragodes tomentosus (LeC.), and Schoenicus puberulus LeC. have been recently associated by rearing series of larvae collected in sandy soil habitats. Adults emerge in summer and are relatively short-lived; the partially grown larvae overwinter. Larvae of B. c. arundinis and E. tomentosus are scavengers of plant debris; Bothrotes adults have been found feeding on pollen of dune plants. Larvae and adults of S. puberulus feed on lichens (Cladonia spp.) on inland sandhills and barrens.

Epitragine pupae, unknown prior to this study, lack the abdominal lateral lamellae found in most other tenebrionids but have unique defense structures that are probably derived from these. Each "gin-trap" consists of a sclerotized, crescent-shaped elevation with a sharp edge that fits into a groove on the opposing segment. The presence of these structures suggests that the winged Epitragini may not be as primitive as has been postulated.

COMPOSITION OF THE GENUS ZOPHOHELOPS RTT. (COLEOPTERA, TENEBRIONIDAE) AND PECULIARITIES OF THE GEOGRAPHIC DISTRIBUTION OF SPECIES OF THIS AND ALLIED GENERA. G.S. Medvedev, Zoological Institute Academy of Sciences, Leningrad, USSR, 199034.

Until recently the majority of species of the subtribe Helopina from Central Asia and southern Kazakhstan (except for species of the genus Cylindronotus Fald.) were placed to the genus Zophohelops Rtt. A study of the structure of the male genitalia has shown the subgenus Reitterohelops Skop. of that genus to be a sharply distinct taxon of the generic rank. Species of the genus Reitterohelops are characteristic for the spring fauna of the foothills in the southern Central Asia (6 species). Species of the Zophohelops are concentrated in West (22 species) and North Tien Shan (2 species). The representatives of the West Tien Shan group live around the snow spots (up to 3000 m) and in the meadows in the valleys. Areas of the genera Reitterohelops and Zophohelops are restricted to different mountain systems of Central Asia.

A MORPHOMETRIC ANALYSIS OF MORDELLISTENA COSTA IN THE SOUTHWESTERN UNITED STATES (COLEOPTERA: MORDELLIDAE). J.C. Burne, Department of Plant, Soil & Insect Sciences, P.O. Box 3354, University of Wyoming, Laramie, Wyoming, U.S.A. 82071.

Beetles of the genus Mordellistena Costa in the southwestern U.S. are submitted to a morphometric analysis in order to obtain more reliable taxonomic characters and to establish the foundations for construction of a phylogeny. Results of measurement of thirty external characters were submitted to a discriminant analysis which reduced the number of significant characters to fourteen. Over 500 specimens were then measured for these characters, and the results then submitted to a cluster analysis. Results of the analysis are discussed as to their taxonomic and classificatory possibilities. Accomplishments of the study include the generation of a list of the species of Mordellistena for Arizona, the discovery of several undescribed species, a more confident method of identification, and the foundation of a phylogeny for the genus. Shortcomings of the analysis were the failure to construct species specific groups and inability to group 100%.

PHYLOGENETIC RELATIONSHIPS BETWEEN THE SIRICIDAE, XIPHYDRIIDAE, SYNTAXIDAE AND ORUSSIDAE (SYMPHYTA, HYMENOPTERA). J.R.WALTHER, Inst. of General Zoology, Free University, Berlin, Fed. Rep. of GERMANY.

Comparative investigations of the morphology and ultrastructure of the antennal sensilla as well as those on the labial palps support the analysis of three hypothesis regarding the phylogenetic relationships between Siricidae, Xiphydriidae, Syntaxidae and Orussidae, which have been proposed by KÖNIGSMANN (1977). Both the morphology of the sensilla on the antennae and the corresponding pattern of sensilla confirm the monophyly of Siricidae and Xiphydriidae. *Syntaxis libocedrii* has a different pattern of sensilla which must be rated as a plesiomorphic character. Nevertheless it must be stated, that Siricidae + Xiphydriidae and Syntaxidae are sister groups. The monophyly of this group is confirmed by a very complex character, the multiple sensillum in a pit on the labellar palps of all wood wasps of the Siricidae, Xiphydriidae and Syntaxidae, studied to date. It appears, that the Orussidae do not possess this multiple sensillum, the function of which is still unknown. Since the pattern of sensilla of the Orussidae does not show similarities, either to those of the Siricidae and Xiphydriidae nor to this of the Syntaxidae, we conclude that the first hypothesis of KÖNIGSMANN is valid, however the phylogenetic relationship between the Siricidae + Xiphydriidae + Syntaxidae and the Orussidae has also to be confirmed, using other characters.

SPECIES OF *PONTANIA* O.COSTA (HYMENOPTERA: TENTHREDINIDAE) ASSOCIATED TO ARCTIC-ALPINE AND OTHER HIGH ALTITUDE DWARF WILLOWS IN THE ITALIAN MOUNTAINS. L. Masutti, Institute of Agricultural Entomology, University of Padova, I-35131, Padova, Italy.

High altitude species of *Pontania* O. Costa from several localities of Italy have been considered with reference to the distribution of their host plants.

In particular, different populations of *Pontania* coexisting on mixed shrubs of some arctic-alpine and other high altitude dwarf willows in the South-Eastern Alps have been examined. The results are as follows: 1) *P. reticulatae* Malaise develops only on *Salix reticulata* L.; 2) *P. retusae* Benson develops only on *S. retusa* L.; 3) a third *Pontania* develops on *S. alpina* Scop.; 4) electrophoretic tests on larvae have revealed a clear-cut separation between the three *Pontania*; 5) no species of *Pontania* has been collected there - or anywhere else - on *S. herbacea* L.

No gall has been found so far on high altitude dwarf willows in the Apennines, where the late summer aridity possibly has an unfavourable effect on the survival of *Pontania*.

PRELIMINARY STUDIES ON THE TAXONOMIC STATUS OF *PEDIOBIUS* SPP. EMERGING FROM LARVAE AND PUPAE OF THE POTATO 28-SPOTTED BEETLE, *HENOSPEPILACHNA VIGINTIOCTOMACULATA* (MOTSCHULSKY). Peng Hua*, Biological Control Laboratory, Chinese Academy of Agricultural Sciences, Beijing, China.

Cross-mating tests involving the mating of *Pediobius feveolatus* (from Hongkong, India, Japan, and Korea) to *Pediobius* spp. emerging from potato 28-spotted beetle larvae and pupae in Beijing were undertaken. The results showed that there was no reproductive isolation between the *Pediobius* which came from Beijing and those from other parts of the world. By using polyacrylamid gel electrophoresis, the population relationship of *Pediobius* from Beijing and India was studied: isozymes analysed included esterase, lactate dehydrogenase, malic dehydrogenase and alcohol dehydrogenase. Three dehydrogenases were found to be monomorphic. Only one different zone existed in esterase. Hence the Beijing *Pediobius* was considered to be *Pediobius feveolatus* (Crowford): only one biotype was recognized.

FAMILY IDENTIFICATION OF *ELASMUS* (HYMENOPTERA: CHALCIDOIDEA) EVALUATION OF CURRENT FAMILY LIMITS. L.D. Coote, Department of Entomology, Royal Ontario Museum, 100 Queens Park, Toronto, Ontario, Canada M5S 2C6.

Parasitic wasps of the genus *Elasmus* were traditionally referred to their own family along with four other genera. This classification is still followed, though most place the four genera in Eriaporinae of Aphelinidae. Others recognize Eriaporinae but place *Elasmus* in its own subfamily in Eulophidae. *Elasmus* is structurally unique in Eulophidae but shares characters diagnostic to Eriaporinae. Previously, there was no phylogenetic analysis to establish monophyly of *Elasmus*, or Eriaporinae, or to support family placement of *Elasmus*. If *Elasmus* is referred to Eulophidae then characters shared with Eriaporinae are convergent. If *Elasmus* is referred to Eriaporinae then characters shared with Eulophidae are convergent. Another alternative is to refer *Elasmus* and Eriaporinae to their own family. Morphological evidence will be evaluated in light of these competing hypotheses.

A PRELIMINARY CLASSIFICATION OF THE MYMARIDAE (HYMENOPTERA: CHALCIDOIDEA) BASED ON THE CHARACTERS OF THE MALE GENITALIA. G. Viggiani, Department of Agricultural Entomology and Zoology, University of Naples, Portici, Italy.

A new classification of the Mymaridae based on the characters of the male genitalia is proposed and compared with the previous systems. According to the types of the male genitalia the following preliminary suprageneric categories are recognized: subfam. *Lymaenoninae* (aedeagus not incapsulated into a phallobase and with jointed apodemes); subfam. *Mymarinae* (aedeagus incapsulated into a phallobase and with bacilliform apodemes), including the tribes Aresconini, Ooctonini, Alaptini, Anagrini, Erythmelini, Mymarini and Anaphini; subfam. *Camptopterinae* (aedeagus not incapsulated into a phallobase and without bacilliform apodemes or other structures). The delimitation of the tribes is given.

NOUVEAU REGARD SUR LA POSITION SYSTEMATIQUE DES CERTAINES GENRES DES ENCYRTIDES ARCHAÏQUES (HYMENOPTERA: ENCYRTIDAE). A.V. Sharkov, Zoological Institute Academy of Sciences, Leningrad 199034 USSR.

L' étude des structures abdominales des encyrtides des genres *Quadrencyrtus*, *Eucoccidophagus*, *Oriencyrtus* et *Mira* fut la base pour la révision de la position systématique des certains taxons supérieurs d' *Encyrtidae*. La tribu *Charitopodini*, considérée avant comme la plus archaïque dans la famille, fut synonymisée avec *Miraini* et céda sa place dans la système phylogénétique aux tribus *Quadrencyrtini* (genres *Quadrencyrtus* et *Eucoccidophagus*), dont les représentants ont conservé un caractère ancien et unique parmi les encyrtides - une large liaison entre les paratergites et les valves extérieures d' ovipositeur, et *Oriencyrtini* (genre *Oriencyrtus*), caractérisée par la présence d'une large liaison entre les paratergites et le IX syntergite. Tous les genres traitées, originellement placées dans la sousfamille *Encyrtinae*, furent transférées dans *Tetracneminae*.

THE TAXONOMIC STATUS OF *MUTILLA* AND *RONISIA*, WITH NOTES ON THE CLASSIFICATION OF THE MUTILLINI (Hymenoptera, Mutillidae). A. Cetković⁽¹⁾ and G. Nonveiller^{(2)*}; ⁽¹⁾ Yu-11000 Beograd, Kumodraška 60; ⁽²⁾ Yu-11080 Zemun, Nušićeva 2a..

Species belonging to the genera *Mutilla* (s.str.) and *Ronisia* have been recognised and described by various authors under several generic/subgeneric names: *Mutilla* L., *Ronisia* Costa, *Barymutilla* André, *Pycnotilla* Bisch., *Macromyrme* Lelej. Their inter-relationships and taxonomic value have been a matter of many changings and misinterpretations. In the last 30 years, *Ronisia* was usually considered as valid, at generic or subgeneric rank (with *Pycnotilla* and partly *Barymutilla* as synonyms), but its inadequate separation from *Mutilla* (specially the males) was still problematic.

Our extensive revisionary study of the subtribe Mutillina (sensu Brothers, 1975) on a great number of representatives from the Afrotropical and Palearctic regions, has shown that *Ronisia* requires a full generic rank. Members of this genus can be easily distinguished from the closely related *Mutilla*, by having a bidentate apex of mandibles in both sexes, while *Mutilla* have tridentate apex. This important character was firstly pointed out by Ashmead (1903), but neglected by practically all subsequent workers. *Pycnotilla* is a junior synonyme of *Ronisia*; *Barymutilla* would be probably retained as a subgenus of *Mutilla*; *Macromyrme* can be applied to one of the approximately 13 species groups recognised within *Ronisia*, but we would rather not suggest the subgeneric division of the genus.

The taxonomic status of other taxa placed in the Mutillina (sensu Brothers, 1975) is briefly discussed, as well as the present status of the whole tribe.

CLADISTIC ANALYSIS AND A BROADER INTERPRETATION OF THE BEE GENUS *CALLIOPSIS* (HYMENOPTERA: ANDRENIDAE).

L. Ruz, Zoologija, Universidad Católica de Valparaíso, Av. Brasil 2950, Valparaíso, Chile.

The bee genus *Calliopsis* Smith has traditionally included four subgenera: *Calliopsis* s.str., *Perissander*, *Calliopsima* and *Verbenapis*. Here, however, it is treated in a broad sense not only to include the genera mentioned above but also *Nomadopsis* s.str., *Macronomadopsis*, *Micronomadopsis*, *Hypomacrotera* and *Liopoeum*.

Morphological studies conducted by Rozen (1951, 1957) and Shinn, 1967 mainly considering male genital structures suggest that these taxa are related to one another, but at the same time they indicate the difficulties to draw lines between some of them. The new concept of *Calliopsis* is based mainly on: (1) the striking similarity of genital structures among the species of some current recognized genera, (2) lack of strong characters for diagnosis, and (3) little morphological differentiation among most of the taxa indicated. The cladistic analysis, in fact, indicates that this is a natural group, supported in the cladogram by some strong synapomorphies that make this group monophyletic.

HISTORICAL ZOOGEOGRAPHY OF THE EUMENINE WASP GENUS *SYMMORPHUS* WESMAEL (HYMENOPTERA: VESPIDAE). J.M. Cumming, Biosystematics Research Centre, Agriculture Canada, Ottawa, Ontario, Canada, K1A 0C6.

Similar phylogenetic and chorological patterns observed in both *Symmorphus* and the Vespinae, in conjunction with the inference on structural grounds that *Symmorphus* is a relatively ancient member of the Eumeninae, suggest that the genus originated in Laurasia towards the end of the Mesozoic. Most of the early evolution within the genus was presumably confined to the Oriental Region, as indicated by the extant distributions of both *S. (Parasymmorphus)* and the *S. hoozanensis* group, with northward expansion into Asia possibly having occurred during the Paleocene. Interruption of the intercontinental Obik sea barrier through Eurasia at the end of this epoch, may have allowed westward expansion of the *S. declivis* + *S. murarius* group clade into Europe, with re-establishment of this barrier in the early Eocene possibly having vicariated the ancestor of each group in Europe and Asia respectively. Expansion of the presently diverse *S. murarius* group westward from Asia, is hypothesized to have occurred after the permanent withdrawal of the Obik sea at the end of the Eocene, with several invasions of the New World having occurred since this time via the Bering land bridge.

PHYLOGENETIC RELATIONSHIPS AND THE ORIGIN OF SOCIAL BEHAVIOR IN THE VESPIDAE (HYMENOPTERA). James M. Carpenter, Museum of Comparative Zoology, Harvard University, Cambridge, MA 02138 U.S.A.

The phylogenetic system of the social wasps is treated. Cladograms for the genera of Stenogastrinae, Vespinae and Polistinae are presented. Implications of the cladograms as a test of West Eberhard's (1978) model for the evolution of social behavior in wasps are discussed. Some fundamental tenets of the model are corroborated, but some of the proposed transitions apparently did not occur.

THE IMPORTANCE OF BODY SIZE IN THE EVOLUTION OF HYMENOPTERAN WINGS. B.N. Danforth* and C.D. Michener, Department of Entomology, University of Kansas, Lawrence, KS 66045, USA

The allometric relationships between body size and several aspects of wing morphology in the Hymenoptera were investigated using multivariate morphometric techniques. The study focused primarily on wing allometry in five monophyletic genera of bees (*Perdita*, *Halictus*, *Ceratina*, *Trigona* and *Apis*), but the patterns of size-related evolutionary change found within each of these genera are also found in numerous other hymenopteran taxa. Increased body size in hymenopteran lineages is correlated with the following changes in wing morphology: (1) decreased relative stigma area, (2) distal extension of wing vein elements, (3) increased aspect ratio and (4) proximal shift in the centroid of wing area. Reversal of these trends accompanies decreased body size. The repeated allometric trends most likely result from adaptive change in wing morphology due to size-related changes in the physical properties impinging on the organism -- principally the quality and magnitude of drag. The fact that similar wing morphologies among distantly related species can result from similarity in body size has important implications for the study of hymenopteran phylogeny, especially at lower taxonomic levels and when a high proportion of wing characters are employed.

THE WORLD REVISION OF LEPTOPODIDAE (HEMIPTERA, LEP-
TOPODOMORPHA). P. Chen* and T. Hejerman, Department of En-
tomology, Agricultural University, Wageningen, The Netherlands.

The family Leptopodidae is one of the important taxa for the
phylogenetic reconstruction of the Leptopodomorpha, and the study of
evolutionary trends in the Heteroptera. So far, more than 30 species
have been reported. The world revision of this family will provide a
valuable basis for phylogeny analysis of this family and other groups.

MORPHOLOGY OF THE PENTATOMIDAE: A SYNTHESIS AND CLADISTIC
ANALYSIS. S.A. Hasan* and G.C. McGavin, Department of
Zoology, University of Oxford, U.K.

A comparative cladistic analysis of the Pentatomidae
based on the examination of seventy five characters in
twenty one tribes, is presented. Seven other pentatomoid
families were also included. The characters used were
taken from new observations on the morphology of external
scent gland apparatus, rostral and pretarsal structures
and from the existing literature. The data were analysed
using the numerical cladistic program PAUP, which gener-
ated one hundred equally parsimonious cladograms. The
character states supporting various alternative subtopolo-
gies were analysed and a preferred cladogram evaluated in
terms of characters and clades. The final classification
of the Pentatomidae is based on this cladogram using con-
ventions for annotated Linnaean hierarchies. The final
classification was compared with the previous classifi-
cations proposed for the family. The Pentatomidae is
recognized as a monophyletic family. The Asopinae and the
Podopinae are reinstated as subfamilies while one subfamily
(Phyllocephalinae) and two tribes (Rhynchocorini and Tropi-
corini) are given a lower rank. Seven taxa forming a
polychotomy provide a basis for the evaluation of other
taxa at the tribal level.

DOES SEXUAL SELECTION EXPLAIN THE DIVERSITY OF
FEMALE GENITALIA IN LETHAEINE SEED BUGS ?
(HEMIPTERA: LYGAEIDAE) Jane E. O'Donnell, Department of
Ecology and Evolutionary Biology, Box U-43, The University of
Connecticut, Storrs, CT. 06268 USA

The morphological diversity of the female spermatheca in the
rhyarochromine tribe Lethaeini is described and analyzed in relation
to phylogeny, morphology of the male genitalia, and sexual selection
theory. The spermathecal types are of systematic significance, not
only varying among species of the same genus, but also differing
considerably among genera in a phylogenetically meaningful way.
This pattern of species-specific genitalic morphology, when it occurs
in males, is generally considered to be a product of sexual selection.
Is sexual selection the most likely explanation for divergence of female
genitalic morphology as well?

The following observations from lethaeine genitalia seemingly
contradict predictions of sexual selection theory: female genitalia are
morphologically diverse; male and female genitalia exhibit parallel
changes in morphology; and female morphology, at least in some
cases, appears capable of excluding males with the wrong genitalia.

FEMALE ACCESSORY GLANDS AND SPERM RECEPTION IN
TINGIDAE (HETEROPTERA). David Livingstone and
M.H.S. Mohamed Yacoob, Division of Entomology,
Bharathiar University, Coimbatore - 641046 INDIA

Under the shadow of suspicion, the accessory glands
in Tingidae have been designated earlier as 'Saccus
seminales', 'Seminal Sacs', 'Sperm sacs', 'Spermathecae',
Spermathecal organs', 'Dorsal sac', 'Unpaired vermiform
accessory glands', etc. Examination of the female repro-
ductive system of over 30 multivoltine, polyandrous
species of Tingidae has unequivocally established the
role of permanent enlargements of the lateral oviducts
and pedicels as sperm storage, in the absence of true
spermathecae. The paired accessory glands have
assumed diverse morphological features and different
types of positional variations. Cantacaderinae type,
having an unpaired median bulbous gland, represents
the prototyp and Eteoneus & Corvthauma, among
Tinginae, represent the two independent lines of evolution
Comparison with other cimiciform groups has been
made and the affinity of Tingidae with Reduviidae
reassessed.

A REVIEW OF THE GENERA OF ISOMETOPINAE (HEMIPTERA:
MIRIDAE) OF THE MIDDLE EAST, EUROPE AND AFRICA.

A.E. Akingbohunge, Department of Plant Science,
Obafemi Awolowo University, Ile-Ife, Nigeria.

The Isometopinae is a small subfamily of bugs
predaceous on scale insects and aphids. Seven genera were
previously recorded for the subfamily in the Middle East,
Europe and Africa namely: Isometopus Fieber, Myioma
Puton, Lindbergiella Carvalho, Magnocellus Smith, Letaba
Hesse, Ptischia Mc Atee & Malloch and Isometopidea Poppius.

It is shown that Letaba is a synonym of Paloniella
Poppius, originally known from the Oriental region. Also,
Magnocellus is synonymized with Isometopus and a new
genus, Smithopus is erected for two species wrongly placed
in it. Similarly, the single species described in
Isometopidea is not congeneric with the type of that genus.
Thus, a new genus Slateropus is erected for it. Two other
new genera, Isometopiellus and Carayonischa are described.

CLADISTICS, BIOGEOGRAPHY AND HOST PLANT RELATION-
SHIPS OF THE RHINOCOLINAE (HOMOPTERA, PSYLLOI-
DEA). D.H. Burckhardt, Muséum d'Histoire naturelle
CP 434, CH-1211 Genève 6, Switzerland.

The Rhinocolinae constitute a small subfamily
of jumping plant lice with about 10 genera and 40
species, and have a world-wide distribution. The
subfamily has been recognized as a natural group
only recently; before the constituent genera were
attributed to several subfamilies. A cladistic
analysis confirms the holophyly of the group, but
the sister-group relationship remains unknown.
The subfamily is divided into 2 groups, one with
a presumed Gondwanian and one with a Laurasian
origin. From the present-day distribution, it is
estimated that the generic diversification took
place 120-100 MY ago (Cretaceous). Fossils from
Dominican amber (35 MY) closely resemble present-
day species. A large portion of the species deve-
lop on plants of the order Rutales, and in parti-
cular on Anacardiaceae; others are linked to
Asteraceae, Cistaceae and Zygophyllaceae. Some
species are gall-formers.

UNIQUE PROBLEMS IN THE SYSTEMATICS OF COCCOIDEA (HOMOPTERA). M. Kosztarab, Department of Entomology, Virginia Polytechnic Institute & State University, Blacksburg, Virginia, 24061, USA.

Taxonomists working on scale insects have to consider such unique problems as: the presence of neotenic females, often without legs and antennae, and with other structures drastically reduced (e.g., Diaspididae); the enormous size differences between teneral females, reproductive and postreproductive females (e.g., Coccidae, Kermesidae); host plant-induced morphological variations, e.g., *Parthenolecanium corni* (Bouché); and site-induced morphs (e.g., *Chionaspis* spp., *Asterolecanium* spp.)

Phylogenetic analyses are often futile when considering the lack of descriptions of adult males and immature stages, and of adequate population samples, also the existing gap in our knowledge when only about 25% of the estimated total species have been described to date.

Solutions are proposed to overcome some of the problems. Advantages of working on this taxon include: the availability of bibliographies, generic lists, and inventories of major collections.

IMPLICATIONS OF THE DISCOVERY OF "REPUGNATORIAL GLANDS" IN *CYBAEOTA* (ARANEAE: AGELINIDAE). R.G. Bennett, Environmental Biology, University of Guelph, Guelph, Ontario, N1G 2W1, Canada.

A recently described type of spider integumentary gland with distinctive cuticular morphology, the repugnatorial glands, has been used to support a hypothesis of sister group relationship between the Telemidae and the Leptonetidae. This paper reports the presence of strikingly similar glands in the distantly related spider genus *Cybaeota* (Agelenidae). The placement of these glands in *Cybaeota* may support the repugnatorial secretion function hypothesis proposed for them in the Telemidae. The phylogenetic implications of the scattered distribution of this character and another, the distinctive series of paired elongate tibial macrosetae, are discussed.

A STUDY OF THE *MONONYCHELLUS* (ACARI : TETRANYCHIDAE) SPECIES COMPLEX FROM SELECTED CASSAVA GROWING AREAS OF AFRICA USING PRINCIPAL COMPONENT ANALYSIS. L.M. ROGO, International Centre of Insect Physiology and Ecology (ICIPE), P.O. Box 30772, NAIROBI, Kenya.

A study of several populations of the cassava green mites from eleven African countries representing wide ranging ecological zones were studied using a multivariate method of Principal Component Analysis. This study revealed that there is only one species of the *Mononychellus* present on cassava in Africa and thereby designated *M. tanajoa*.

A DATABASE ON ENTOMOLOGY "KONCHU" BASED ON JAPANESE ENTOMOLOGICAL JOURNALS. O. Tadauchi, Entomological Laboratory, Faculty of Agriculture, Kyushu University, Fukuoka 812, Japan.

A public database on Entomology "KONCHU" based on Japanese Entomological journals since 1900 is produced in the Computer Center of Kyushu University. The KONCHU is open to the public and is used in the universities and institutions of Japan by a network system. One taxon which has a scientific name or Japanese name described in one article is treated as one record in the KONCHU. The items are as follows: scientific name (TAX), Japanese name (JTAX), author (AU), title (T), journal (J), volume, no. and page (VNP), year (Y), order (OR), family (FAM), synonym (SYN), distribution (DST), and key words (KEY). Presently three files, named MUSHI (1928-1985), ESAKIA (1960-) and KONTYU (1917-) are produced. The outline of the database is presented.

AFTER 35 YEARS AGAIN: WHY WORSHIP TYPES. L. Papp, Zoological Dept., Hungarian Natural History Museum, Budapest, Hungary H-1088.

F. Zumpt's question (Rev. Ecuat. Ent. Par., 1(3):87-89) posed 35 yrs ago has not been adequately answered, because a good part of the methods of taxonomy, incl. the type-concept codified in the Intl Code Zool. Nomencl., compel taxonomists to adopt the way of thinking of the 19th century. The usage we apply determines two kinds of "traps": 1/ Type-specimens of doubtful names from former inadequate descriptions should be studied; their accessibility is however misunderstood by fellow taxonomists (i.e. it is the duty of curators to send all types at once). 2/ Curators have to worship types for their salary; they do not readily loan them not only for fear of damage through transportation but because of the high risk of damage or destruction caused by heavy-handed taxonomists performing "genital preparations". Former concepts of types as "the property of science" proved to be unenforceable fictions. It is proposed that all future descriptions of new species be valid only by depicting differentiating characters in an identifiable way to avoid later re-examinations. The above problems are of a methodological nature requiring a new consensus of taxonomists. Therefore a proposal is made to the XVIII Intl Congr. Ent. for an ad hoc committee with a commitment to proposals for a radical reform of the Code in accordance with our task to serve biological sciences of the 21st century.

INSECTS USED AS FOOD IN MEXICO. Julieta Ramos-Elorduy José Manuel Pino M. Instituto de Biología UNAM. Apdo Postal 70-153 México D.F.

Insects are a renewable natural resource fairly used as food by people in many communities of the rural areas in the Mexican Republic. This kind of food is mostly consumed by people who live in the States qualified with bad and very bad nutrition, in this way they can get high nutritive value nutrients (proteins, vitamins, fats, etc.). These compounds give them a lot of calories needed for their life.

Now a days, we have recorded 241 species of edible insects, both aquatic and terrestrial, whose consumption is generally made in immature stages (eggs, larvae, or pupae). These species are eaten separately, and sometimes together.

The ingestion of these insects varies according to the season of the year, existing a sequence of them. These insects belongs to: Ephemeroptera, Odonata, Orthoptera, Anoplura, Hemiptera, Homoptera, Neuroptera, Coleoptera, Trichoptera, Lepidoptera, Diptera, and Hymenoptera Orders.

They are eaten mainly roasted and fried.

#1

A BIOSYSTEMATIC STUDY OF THE GENUS *ATHALIA* LEACH OF JAPAN (HYMENOPTERA: TENTHREDINIDAE). Masaki Abe, Entomological Laboratory, Faculty of Agriculture, Kyushu University, Fukuoka 812, Japan.

The Japanese species of the genus *Athalia* Leach, 1817 are revised. Seven species and one subspecies are recognized not only from the morphological characters of the adults and larvae including chromosome number but also from the biological knowledge such as host plants, life cycle, habits, natural enemies, distribution, and electrophoretic analysis of the larval hemolymph protein. Seven species are *A. japonica* (Klug, 1815), *A. infumata* (Marlatt, 1898), *A. proxima* (Klug, 1834), *A. rosae ruficornis* Jakovlev, 1888, *A. kashmirensis* Benson, 1932, *A. yanoi* Takeuchi, 1952, stat. nov. and *A. scutellariae* Cameron, 1880. The latter is recorded from Japan for the first time.

#2

A NEW SPECIES OF PISON JURINE FROM BALTIC AMBER (HYMENOPTERA: SPHECIDAE). A.V. Antropov and W.J. Pulawski*, Zoological Museum, Moscow State University, Herzen Street 6, Moscow 103009, USSR and Department of Entomology, California Academy of Sciences, Golden Gate Park, San Francisco, California 94118, USA

A new species of *Pison* found in Baltic amber is a member of the subgenus *Entomopison* whose extant members occur only in the Neotropical Region.

#3

HOST PLANT CHOICE BY SOME SOUTH AMERICAN OEDIONYCHINA (CHRYSOMELIDAE, ALTICINAE). A. Begossi* & W. W. Benson. Depto. de Zoologia, IB, UNICAMP, 13081, Campinas, SP, Brazil.

The Oedionychina consists of a close knit group of mostly tropical alticines. The importance of Verbenaceae as Oedionychina host plants has been stressed in the literature. Food plant preferences of *Alagoasa* (8 spp.), *Homophoeta* (3 spp.) and *Asphaera* (1 sp.) in laboratory feeding choice experiments confirm that plants with which beetles are found associated in the field are highly acceptable host plants. The species of *Alagoasa* studied fed most often on Verbenaceae, followed by Acanthaceae, Bignoniaceae and Compositae. Feeding by *Homophoeta* and *Asphaera* was concentrated on Labiatae, and secondarily on Verbenaceae. The taxonomic relatedness of these host plants and their frequent possession of terpenes suggests that the Oedionychina may have diversified through a process of adaptive radiation over chemically similar hosts.

#4

CUTICULAR HYDROCARBON PATTERNS OF *BLATTELLA* COCKROACHES. D.A. CARLSON AND R.J. BRENNER, Insects Affecting Man and Animals Research Laboratory, Agric. Res. Serv., U.S. Dept. Agric., Gainesville, FL USA 32604.

The identification of various life stages of several species of *Blattella* cockroaches was accomplished by using gas chromatography to quantify their cuticular hydrocarbon waxes. Dried and frozen specimens of wild and lab samples of the closely related and morphologically very similar species, *B. asahinai* (Asian cockroach) and *B. germanica* (German cockroach), were identified by inspection of chromatographic data. Their patterns were compared to those of the closely-related *B. bisignata* and *B. lituricollis* and the more distantly related *B. vaga*. A statistical technique is described for numerical pattern recognition of data to identify Asian and German cockroaches. It was successfully applied to blind samples of whole cockroaches, nymphs, oothecae, legs, wings, or cast skins from German-like cockroaches, as well as hybrids of Asian and German cockroaches.

#5

SEM IDENTIFICATION OF ALL INSTARS OF CERATITIS CAPITATA, DACUS CUCURBITAE, D. DORSALIS, D. LATIFRONS, AND D. TRYONI (DIPTERA: TEPHRTIDAE). L.E. Carroll, Texas A&M University, College Station TX 77843.

Tephritid larvae are difficult to identify accurately. The mature larvae of even the most economically important species are poorly known, and knowledge of the eggs, early instars, and puparia is even more limited.

The sense organs of the cephalic segment are rarely completely and accurately described for tephritid larvae. The stomal organ (=ventral organ), in particular, because of its small size, has been largely ignored.

All instars of the five species listed were obtained from laboratory cultures. A series of 10 each of third instars and 5 each of first and second instars were examined by SEM. The morphology of the stomal sense organ and associated structures was found to be useful in accurately identifying to species all three larval instars of pest species in the economically important genera *Ceratitis* and *Dacus*. An illustrated key to instars and species is provided.

#6

BEHAVIOUR OF *TOPOMYIA YANBARENSIS* MIYAGI (DIPTERA, CULICIDAE) IN THE LABORATORY. Chin-Seng Chen, Department of Biology, Tunghai University, Taichung, Taiwan, Republic of China.

Topomyia yanbarensis Miyagi, 1976, a rare mosquito of Taiwan, breeds in beetle-bored bamboo below 500 m around the island. Observations, using 25 x 34 x 26 cm cages in the laboratory, showed that mating and oviposition takes place during the daytime. Male swarming was not found in this study. Oviposition of the autogenous female begins on the 9th to 12th days after emergence. Habitat and oviposition site preference have been investigated in the laboratory. *T. yanbarensis* lays its eggs in bamboo internodes with small apertures, most of which are too small to admit this mosquito. Oviposition occurs while the mosquito is hovering or staying in front of the aperture, and the eggs are projected horizontally. There is no significant difference in utilization for oviposition between bamboo and plastic tubing with the same circumference and artificial punctured holes. There are no significant differences among three sizes of bamboo (<18.5 cm in circumference) utilized for oviposition. Mating behaviour and the process of emerging adults escaping from bamboo internodes are described in detail.

#7

THE GERRID FAUNA OF CHINA (HEMIPTERA, GERROMORPHA). P. Chen* and N. Nieser, (P.C.) Department of Entomology, Agricultural University, 6700 EH Wageningen, The Netherlands; (N.N.) Htg. Eduardst. 16, 4001 RG Tiel, The Netherlands.

The gerrid fauna of China is not well known. Current knowledge of composition and distribution is summarized, with emphasis on the genus of *Matrocoris* in S.E. Asia.

#8

PHYTOPHAGOUS INSECT FAUNA OF *CENTAUREA SOLSTITIALIS* L. (ASTERACEAE, CARDUEAE) IN ITALY AND GREECE. S.L. Clement, USDA, ARS, Plant Introduction Station, Washington State University, Pullman, WA, USA, 99164-6402.

Thirty-seven species in 5 orders, 16 families, and 22 genera are reported as comprising the insect fauna that use *C. solstitialis* (yellow starthistle) as a breeding host in Italy and Greece. Information regarding the distribution and abundance, host specificity, and host-plant relationship of these species was assembled from literature sources, taxonomic specialists, and from personal field surveys and formal host testing conducted between 1983 and 1986. This information is needed to identify potential biological control agents for *C. solstitialis*.

The composition of the fauna is 43% polyphagous (attack other genera besides *Centaurea*), 30% oligophagous (restricted to *Centaurea*), and 19% monophagous (restricted to *C. solstitialis*); host ranges are unknown for 8%. Most of the insects are endophagous (87%) and capitulum-infesting (68%) species. All 18 oligophagous and monophagous insects are endophagous species and 14 of these attack buds and flower heads (6 tephritid flies; 5 curculionid beetles; one bruchid beetle; 2 gelechiid moths). This group includes the flower head weevil *Bangasternus orientalis* (Cap.), introduced and established in the U.S.A. for the biological control of *C. solstitialis*.

#9

PHILORNIS CARINATA DODGE, 1968 (DIPTERA: MUSCIDAE) – DATA ON MORPHOLOGY, BIOLOGY AND TAXONOMY. M.S. Couri*, Museu Nacional, Quinta da Boa Vista, 20.942, Rio de Janeiro, Brazil

A nestling of *Myiarchus* sp. (Passeriformes: Tyrannidae) parasitized by *Philornis* larvae was found by Dr. Miguel Monné (Museu Nacional, RJ) in Quinta da Boa Vista. The subcutaneous larvae was specially located on dorsum, wings and one at base of beak. They were allowed to pupate and the adults emerged in ten to twelve days. The bird was maintained in a cage with newspaper on the bottom. Dr. Monné had fed the bird with a varied diet and the bird survived. Seven larvae, three pupae and three adults (two males and one female) were given by him. The species was *Philornis carinata* Dodge, 1968 known only from adult male, so I could record for the first time the morphology of larvae, pupae, adult female as well as male genital segments. The known larvae of *Philornis* are associated in different ways, with birds, and the subcutaneous type seems to be the most specialized one.

#10

INSECTS AND CANNABIS: PROOF OF CANNABIS IMPORTATION INTO NEW ZEALAND. T.K. Crosby*, J.C. Watt, (Entomology Division, DSIR), A.C. Kistemaker, and P.E. Nelson, Chemistry Division, DSIR, Private Bag, Auckland, New Zealand.

Chemical methods have proved unsatisfactory for identifying the origin of cannabis plant material imported into New Zealand. However, the identification of insects intimately associated with the cannabis can allow the exact location of the origin. The circumstances of the successful use of this approach to prove the importation of cannabis plant into New Zealand are described.

#11

#12

SYSTEMATIC AND ECOLOGICAL SIGNIFICANCES OF *SPHINGONOTUS* SPECIES IN KARAJ GEOGRAPHICAL REGION. Parvaneh Azmayesh Fard, Entomology Department, Faculty of Agriculture, University of Tehran, Karaj-Iran.

Ten *Sphingonotus* species have been collected and identified, and their bioecological significances investigated for three years at five collecting sites. Identification was based mainly upon male epiphallus comparison and certain other morphological characters such as pronotal carenes and sutures, vein venation, tympanal lobes, colour and pattern of hind femur, etc. Most of the species inhabit dry desertic zones, but a few occur in cultivated areas and on the sandy shores of the seasonal rivers. Population density of these species have been estimated and are discussed.

#13

Some Insect Species Common in the State of Qatar. R.M. Abdul and N.F. Shaumar, Department of Zoology, Faculty of Science, Qatar University, Doha, Qatar and Department of Entomology, Faculty of Science, Ain Shams University, Cairo, Egypt.

The peninsula of Qatar occupies the Eastern part of the Arabian peninsula. The present investigation gives an account of the entomofauna of Qatar. The collected insects included 212 species related to 186 genera belonging to 68 families and pertaining to 15 orders namely: Thysanura, Ephemeroptera, Odonate, Orthoptera, Dermaptera, Embioptera, Isoptera, Dictyoptera, Anoplura, Hemiptera, Neuroptera, Lepidoptera, Diptera, Coleoptera and Hymenoptera.

The seasonal distribution at different localities in Qatar together with the type of host plants were studied. Some insect species of butterflies, beetles and grasshoppers are abundantly found during the summer season only. The rest were seasonally dependent. Studies on the harmful effects of some species of white ant (termites) were carried out.

#14

GALL-MIDGES (DIPTERA, CECIDOMYIIDAE) FROM FABACEAE IN KAZAKHSTAN. Z. A. Fedotova, Institute of Zoology, Akademgorodok, Alma-Ata, 480032, USSR

Gall-midges in Kazakhstan are known from plants of 46 families. 25% or 81 species from 22 genera of hosts are Fabaceae, 56 species of phytophagous are developed on them, 18 species are monophagous, 37-narrow oligophagous, 8-inquilines, 5-predators, 3-micetophagous. 6 from 12 genera - Halimodendromyia Marik., Bremiola Rübs., Lathyromyza Rübs., Sophoromyia Fedotova, Desertomyia Marik., Anabremia Kieff. - are distributed only on the Fabaceae. But majority of species concerns to genera Dasineura Rd., Jaapiella Rübs., Contarinia Rd. Gall-midges from simple galls (leaf, flower, fruit and gemma). Most part of species are distributed on shrubs in deserts and perennial herbs in mountains (especially in the forest zone). There are Euro-Siberian and Turanian faunistic elements from the plants of corresponding groups.

#15

COMPARATIVE STUDIES OF COMMUNITIES OF WASPS AND BEES IN SEMI-ARID (KARROID) AREAS IN SOUTH AFRICA. F.W. Gess* and S.K. Gess, Albany Museum, Grahamstown 6140, South Africa.

Whether there is for wasps and bees in karroid areas a characteristic community structure and to what degree the specific composition within a community varies between different regions in the Karoo is currently being investigated by the authors.

Comparative studies between communities of wasps and bees are being undertaken. Sites are being selected which offer a comparable range of nesting situations and substrates. The populations of wasps and bees are sampled for species representation and the nesting biologies of individual species are investigated making it possible to categorise the species following an ethological classification devised by the authors. Once the species are categorised in this manner their positions within community structures readily become apparent.

A detailed community study (Gess, 1981) carried out at a site north-west of Grahamstown is used as the model for comparative studies at other localities. A discussion of some of the findings to date follows.

#16

BOURNIER'S APPARATUS, A WORTHY KEY CHARACTER FOR SPECIES IDENTIFICATION OF PHLAEOTHRIPINE THYSANOPTERA. K. Haga, Institute of Biological Sciences, University of Tsukuba, Tsukuba-shi, Ibaraki 305, Japan.

Some of the phlaeothripine genera have a developed Bournier's apparatus (BA) which is situated on the dorsal wall of vagina at the aperture of spermathecal duct. The structure of BA is highly species-specific, of very low variability, and presents in either preserved materials in alcohol or balsam-mounted specimens macerated with caustic alkali. Therefore, BA may be one of the most useful characters for the species identification in those genera such as Bactrothrips, Elaphrothrips, Megalothrips and Liothrips.

BA can be observed by a simple technique to dissect posterior segments of female abdomen, but it is hardly examined in mounted specimens, even though they are well decolorized. To examine BA structure of the mounted specimen in detail, we must make the specimen be free in balsam-solvent and remount it after removing its BA which needs to be mounted under a separate cover slip.

BA structures of the Oriental species of the genus Bactrothrips Karny (Idolothripinae) are comparatively studied, and those species are clearly identified using the newly employed key character.

#17

PALAEORHIZA: GENUS OF NEW GUINEA (HYMENOPTERA, COLLETIDAE). Y. Hirashima, Department of Entomology, Kyushu University, Fukuoka 812, Japan

Systematic study of the bee genus Palaeorhiza reveals that it contains more than 200 species which may be divided into many subgenera and species groups. Most of them are colorful and lovely insects. Generic classification of the Hylaeinae (which include Palaeorhiza) of New Guinea and Australia will also be discussed.

#18

ACYRTHOSIPHON SPECIES OF IRAN. S.H. Hodjat, Department of Plant Protection, College of Agriculture, University of Shahid Chamran (Ahwaz), Ahwaz, Iran.

The species of Acyrtosiphon and their host plants in Iran are: A. gossypii - Malvaceae and Zygophyllaceae; A. malvae - Malvaceae; A. pelargonii - Geraniaceae; A. pisum - Leguminosae; A. cyperissae - Euphorbiae; A. lactucae - Lactuca; A. scariolae - Lactuca; A. dirhodum - Rosa and Graminae; A. thraucis - Euphorbia; A. rhodobium porosum - Rosa; A. astragalulkae and A. kondoi - various host plants. The last three species are difficult to separate. Biology and characters which may help in separating Acyrtosiphon species in Iran are described and a key is given to identify apterous viviparous forms.

#19

THE APHID FAUNA OF FRUIT TREES IN EGYPT. I.I. Ismail*, S. El-Nagar and A.A. Attia, Department of Economic Entomology & Pesticides, Faculty of Agriculture, Cairo University, Cairo, Egypt.

The survey study on 14 fruit trees, viz. noval orange, baladi orange, mandarin, lime, peach, apricot, guava, pear, apple, mango, banana, plum, grape-vine and pomegranate trees, revealed the presence of 8 species. These are: Aphis gossypii, Aphis punicae, Aphis craccivora, Hyalopterus pruni, Eriosoma lanigerum, Pentalonia nigronervosa, Myzus persicae and Aphis nerii. A. gossypii occurred on 8 fruit trees as soon as the new growths appear. H. pruni was found on each of peach, apricot and reeds. Both of E. lanigerum and P. nigronervosa occurred on apple trees and banana plants, respectively. A. punicae was found on pomegranate trees and duranta plants. A. craccivora was found on citrus trees, only in Quena and Assiut provinces. Both of M. persicae and A. nerii were found on citrus trees in Qualubia province.

#20

TAXONOMY, ZOOGEOGRAPHY AND PHYLOGENY OF THE TRIBE PHISIDINI (GRYLLOPTERA: TETTIGONIOIDEA). X.-B. JIN, LYMAN ENTOMOLOGICAL MUSEUM, MACDONALD COLLEGE, MCGILL UNIVERSITY, STE. ANNE BELLEVUE, QUEBEC, CANADA, H9X 1C0.

The tribe currently belongs to the subfamily Listrosce-lidinae of the family Conocephalidae. After a taxonomic revisional work, a new concept for the tribe is proposed. The species of this group are widely distributed on the islands of varying sizes of the Old World tropics. An elaborate distribution pattern is indicated. A cladogram at species-group level based on detailed morphological character-analysis is suggested, whereby the tribe can be considered a monophyletic group. On the basis of available biology and relevant knowledge of the geological history of these areas, it has been assumed that the tribe has a Gondwanaland origin. The present distribution pattern is the result of both vicariance (the northward drifting of the Indian land mass and the formation of various continental islands). This concept can also explain the fact that the endemic species mostly occur on continental islands and that only two species, *Phisis holdhausi* Karny and *Phisis willemsi* Kevan are particularly widely distributed on oceanic islands. (Permanent address: Shanghai Institute of Entomology, Academia Sinica, 225 Chongqing Road, Shanghai, China.)

#21

METAPHASE CYTOLOGY AND CHROMOSOME BANDING IN CARABID BEETLES. D.-H. Lankenau*¹ and F. Weber²; Dpt. of Molec. and Devel. Genetics, University of Nijmegen, Toernooiveld, 6525 ED Nijmegen, The Netherlands¹; Inst. of Zool., University of Münster, Schlossplatz 5, 44 Münster, W. Germany²

For a long time Carabid beetles attracted attention not only because they represent the largest family of insects but also because of their universal ecological distribution over the entire world. Their morphology and physiology is adapted to such extreme habitats as deserts, caves, boundaries of snowfields in high altitudes of mountains or in the arctic. Some Carabids even hunt under water or dig in the mud of intertidal zones. Until now it has been neglected to correlate any intrinsic evolution of the genome to a certain extrinsic ecological factor. We attempted a first step into this direction by comparing two closely related species with different ecological requirements, *Pterostichus oblongopunctatus* and *P. angustatus*, in regard to their chromosome banding patterns. We demonstrate a method of metaphase chromosome preparation which allows the differentiation between the chromosomes by chromosome banding. The chromosomes 1(Po), 2(Po), X(Po), Y(Po) and X(Pa) of *P. oblongopunctatus* and *P. angustatus* are defined by their fluctuant banding patterns.

Difficulties in interpreting cytological results are discussed.

#22

CLADISTIC ANALYSIS OF PRIOCYPHUS HUSTACHE AND RELATED GENERA (COLEOPTERA: CURCULIONIDAE). A.A. Lanteri* and J.J. Morrone, División Entomología, Museo de La Plata, 1900 La Plata, Argentina.

The main objective of this study was to determine the relationships among the taxa assigned to the genera *Priocyphus*, *Cyrtomon*, and *Mendozella*. The monophyletic units were: 1-*P. humeridens*; 2-"*P. bosqi* species group" (*P. bosqi*, *P. hustachei*, *P. inops*, and *P. kuscheli* sp. nov.); 3-"*P. viridinitens* species group" (*P. viridinitens* and *P. paraguayensis* sp. nov.); 4-*Cyrtomon* (*C. gibber*, *C. inhalatus*, *C. pistor*, *C. luridus*, *P. ovalipennis*, and *P. glaucus*); 5-*Mendozella curvispinis*. *P. hirsutus* was not included because no material was available. The identification of the thirty relevant characters was made by out-group comparison with *Lamprocyphus*. The data set was analysed using Swofford's package PAUP 2.4.1. A cladistic hypothesis is presented as a single asymmetrical cladogram where the phylogenetic sequence of the terminal taxa is: "*P. viridinitens* species group", *Cyrtomon*, *Mendozella*, *P. humeridens*, and "*P. bosqi* species group". The last one retain the name *Priocyphus*; "*P. viridinitens* species group" and *P. humeridens* are new genera.

#23

DISTRIBUTION OF AQUATIC INSECTS IN SUBARCTIC PEATLANDS. D.J. Lewis, Department of Entomology, Macdonald College of McGill University, Ste-Anne-de-Bellevue, Québec, Canada H9X 1C0.

Peat samples were collected weekly from a subarctic fen in Labrador during the summers of 1985-87. Aquatic insects and other invertebrates were removed from the peat by wet extraction techniques. Dominant insects consisted of several families of Diptera (Chironomidae, Ceratopogonidae, Tabanidae and Tipulidae); Odonata, Coleoptera and Trichoptera were less common. Preliminary analyses suggest that the distribution and abundance of aquatic insects of peatlands may be influenced by the nature of the substratum, peatland flora and water levels.

#24

EVOLUTION OF CARNIVORY AND FEEDING STRATEGIES IN REDUVIIDAE OF WESTERN GHATS, INDIA. David Livingstone*, C. Murugan and G. Ravichandran, Division of Entomology, Bharathiar University, Coimbatore - 641046 India.

In phytophagous Hemiptera the rostrum is usually four-segmented, extending beyond the metasternum, irrespective of the length of the anteocular area. Carnivory in Heteroptera is characterized by the shortening and reduction in number of rostral segments, and in Reduviidae, with the development of the stridulatory groove of the prosternum; the rostrum never exceeds the limit of this groove, irrespective of the length of the anteocular area. Examination of more than 160 species of Reduviidae of Western Ghats, India, indicates that shortening of the head is invariably accompanied by acute curving of the middle segment, a feature that characterizes the tibiaolate group of Reduviidae of the drought-prone ecosystems, that engage the tibiaolia of the fore and mid tibiae for securing a vagrant pray. The dimorphism of maxillary stylets in Reduviidae is a perfection in carnivory. With the exception of Holoptillinae, the mandibular stylets in each species are isomorphic, but their shape and arrangement of serrations vary, depending on the specialization in carnivory: spatulate in the myriophagous Ectrichodinae and serratedly pointed in all other entomophagous and haematophagous subfamilies.

#25

CHARACTERIZATION OF GRASSHOPPER GLACIER. J. A. Lockwood, R. A. Nunamaker and R. E. Pfadt, Department of Plant, Soil and Insect Sciences and USDA-ARS Arthropod-borne Animal Diseases Research Laboratory, Laramie, Wyoming 82071.

Grasshopper Glacier is located in the Beartooth Range of Custer National Forest in Park County, Montana. Since 1900, the glacier has been reduced in size by over 50%, and in the past 35 years the glacier has continued to recede dramatically. There now remains virtually no whole bodies of grasshoppers but thousands of body parts in peat-like deposits on the glacier's surface. These deposits consist primarily of mandibles, femora, tibiae, tentoria and tarsi. Despite early reports of stratified deposits, pits dug to a depth of 1 m did not reveal any deeper layers of grasshoppers. Carbon dating of samples extracted from widely separated locations on the glacier indicate that the grasshopper remains are from a single depositional event which occurred 775 ± 85 years ago. Based on earlier records and comparisons of collected material with museum specimens, it appears that the deposits may consist of the extinct Rocky Mountain locust, *Melanoplus spretus* (Walsh). Biochemical analyses are being used to confirm this preliminary finding.

#26

CARABID BEETLE FAUNA AND DISTRIBUTION IN THE BASHKIR STATE RESERVATION : PRELIMINARY RESULTS. A.B. Matveev, Natural department, Bashkir State United Museum. USSR, 450022, Ufa-22, Mendeleyeva, 9/1, fl. 64

Lately a lot of scientists of different countries pay attention to the study of carabids in national parks and reservations. During the summer and autumn 1986-1987 species composition, seasonality and character of carabids domination were studied in the Bashkir State Reservation situated in the hardwood - light coniferous highland province of the mountain - forest area of the Southern Urals. The study was conducted by means of pitfall traps, by hand catching and other methods in 10 stations. More than 3000 individuals of 82 species were caught. The richest in number are genera *Carabus* (8 species), *Pterostichus* (9), *Amara* (11). The richest species variation is fixed in two meadow stations (24 and 28), flood plain thicket (28) and in birch forest (23). The poorest in species variation are two types of steppe (8 and 5). Dominating species in each station and seasonality of 18 mass species are marked. The greatest fauna similarity is fixed for forest stations. Brief zoogeographical analysis is also given.

#27

THE DISTRIBUTION OF DIFFERENT MEMBERS OF THE *SIMULIUM METALLICUM* COMPLEX IN MEXICO. A.L. Millett, Overseas Development Natural Resources Institute, College House, Wrights Lane, London W8 5SJ, U.K.

Simulium metallicum, a secondary vector of onchocerciasis in Mexico, is a species complex (J. Conn, in press). Four different cytotypes have been identified within the Chiapas onchocerciasis foci: all four (types A, B, H and I) in the southern focus, sometimes sympatrically, and two (types A and I) in the northern focus. *S. metallicum* was also found in the Oaxaca focus but the samples have not yet been identified. Larvae attributable morphologically to *S. horacioi* Okazawa and Onishi (a morphospecies within the *S. metallicum* complex), comprised individuals of at least two different cytotypes (types H and I).

#28

PHYLOGENETIC RELATIONSHIPS AND DISTRIBUTION OF THE GENUS *CHRYSINA* KIRBY (COLEOPTERA: SCARABAEIDAE: RUTELINAE). M.A. Morón. Instituto de Ecología. Apdo. Postal 18-845, 11800 México, D.F. México.

The genus *Chrysina* comprises seven species distributed in the mountains of Mexico and Honduras, Central America. The first species group is formed by *C. macropus* Franc., widespread in the humid slopes of Sierra Madre Oriental and Sierra Madre del Sur, between 1000-2000 m altitude; *C. triumphalis* Morón, restricted to the very humid montane forests of Southern Chiapas at 1800 m altitude; *C. modesta* Sturm, limited to certain oak forests from the Neovolcanic System; and *C. karschi* Nonfr. apparently isolated in the San Pedro Sula area. The second species group is composed by *C. erubescens* Bates and *C. beckeri* Bates, that live in the pine-oak forests of Sierra Madre Occidental, between 1900-2900 m altitude; and *C. amoena* Sturm, present in a limited area at the North of Mexico City, at 2400-2600 m altitude. *Chrysina* is closely related with the genus *Plusiotis* Burm., specially with the species group "prasina", well represented in the Sierra Madre del Sur, proposed area for the early diversification of the two groups of *Chrysina*.

#29

ON THE GENUS *TRIGONASPIS* (HYM., CYNIPIDAE) IN EUROPE WITH DESCRIPTION OF A NEW SPECIES FROM SPAIN. J. L. Nieves Aldrey Museo Nacional de Ciencias Naturales (Entomología), J. Gu-tierrez Abascal 2, 28006 Madrid, España.

Up to present date genus *Trigonaspis* Htg. (Hym., Cynipidae, Cynipinae) comprises four described species in Europe: *T. synaspis* Htg. and *T. megaptera* (Panzer) have a wide area of distribution in Europe whereas two species: *T. bruneicornis* Tav. and *T. mendesi* Tav. seem to be confined to Iberian Peninsula. A new species is added now to the list, *T. baeticus* n. sp. described from material reared from galls collected on *Quercus canariensis* in south of Spain.

Taxonomic status of the five known now in Europe is discussed. A key for agamic females is provided and galls figured. Bisexual generation alternating in the heterogonic life-cycle rest unknown in the case of the three species confined to Iberian Peninsula. They appears to form a very closely allied group or sibling species, almost morphologically indifferenciate but well segregated with regard to morphology of the galls and host plant data.

#30

A PRELIMINARY SURVEY OF APHIDS (HEMIPTERA:APHIDIDAE) IN THE WESTERN CANADIAN ARCTIC. Rose O'Doherty* and Richard A. Ring, Department of Biology, University of Victoria, Victoria, British Columbia, Canada V8W 2Y2.

Until recently (Richards, 1963) no aphids had been recorded from the Canadian Arctic; that study, and the few that have been made since, have dealt with that part of the arctic east of Cambridge Bay, Victoria Island. In 1985, *Aphis epilobii* were collected from fireweed (*Epilobium angustifolium*) at Inuvik, Northwest Territories, situated on the treeline in the western portion of the Canadian Arctic (O'Doherty & Ring, 1987). Another trip to Inuvik and further north during the summer of 1987 has identified a further five aphid species from willow (*Salix* sp.), birch (*Betula* sp.) and alder (*Alnus* sp.). Information about these species will contribute to the Biological Survey of Canada (Terrestrial Arthropods) and taxonomic work at the British Museum (Natural History) in London, U.K. A full account of this survey and the species collected will be presented at the Congress.

O'DOHERTY, R. and RING, R.A. (1987). Can.J.Zool. 65, 763-765.

RICHARDS, W.R. (1963) Can.Ent. 95, 449-464.

#31

SYSTEMATIC STUDY OF LEPIDOPTERA (HETEROCERA) IN KOREA, WITH A FAUNAL RELATIONSHIP BETWEEN KOREA AND HER ADJACENT COUNTRIES. K. T. Park, Dept. of Plant Protection, Kangwon National Univ., Chuncheon, 200 Korea.

From the point of view of zoological regions, Korean peninsular belongs to Manchurian subregion as well as N. China and Japan. Lepidopterous fauna of Korean peninsular has not been studied extensively compared to Japan which has a remarkably large number of species described. Research on Heterocera, in taxonomical sense, in Korea was initiated from 1882 by European entomologists and collectors such as A.G. Butler, J.H. Leech and others, and then further works were conducted by Japanese entomologists during the period of Japanese occupation (1910 - 1945).

The initiation of the study on Korean Heterocera by Korean was made after 1947. Writer examined the past and current development of taxonomical study of Heterocera in Korea by a careful analysis of their components and by comparing to those of adjacent countries. From the results, it has been realized that the fauna of Korea is a whole similar to that of Japan, however, it also should be considered with China and Amurland.

#32

A FAUNISTIC SURVEY OF THE SCARABAEIDAE (COLEOPTERA) OF NEBRASKA. Brett C. Ratcliffe, Systematics Research Collections, W-436 Nebraska Hall, University of Nebraska, Lincoln, Nebraska 68588-0514, U.S.A.

The scarab beetles of Nebraska have been comprehensively reviewed. Within the state, 197 species are known to occur (13% of the North American taxa). These species represent 12 subfamilies as follows: Aphodiinae (50), Scarabaeinae (18), Geotrupinae (14), Ochodaeinae (3), Ceratocanthinae (1), Troginae (21), Melolonthinae (55), Rutelinae (10), Dynastinae (8), Cetoniinae (13), Trichiinae (3), Valginae (1).

One new species of arenicolous *Aphodius* was discovered, and 28 species (14% of the scarabs in the state) are recorded for the first time as being from Nebraska.

Nebraska, with its central location on the continent, is a pivotal state for Scarabaeidae because eastern and western faunal elements as well as northern and southern faunas converge here as in no other state. Although primarily a prairie state, Nebraska has many diverse habitats ranging from eastern deciduous forests, short and tall grass prairies, a large section of sandhills prairie, and a small, western component of Rocky Mountains forest. The beetle fauna is also diverse and reflects these differences in biotopes.

#33

CONCENTRATION OF COPPER IN DERMAPTEROUS AND ORTHOPTEROID INSECTS BY ATOMIC ABSORPTION SPECTROSCOPY. S.OKUDA, K. TERATA AND S.SAKAI*, Institute of Biology & Life Sciences, Daito Bunka University, Takasaka, Saitama, Japan, 355

For chemotaxonomic study, the authors have carried the comparison of some essential trace metals contents of Dermapterous and Orthopteroid Insects. Some of them were reported in Bulletin of Daito Bunka University, 1982-88. In this session, the authors show the copper contents.

The concentration of copper in the whole body of Dermapterous and Orthopteroid Insects belonging to 8 families, 12 subfamilies, 15 genera, 17 species and 2 forms, and several parts of body of a Dictyoptera, *Peripraneta americana* L. were determined in ppm by Atomic Absorption Spectrometry. In general, it seems to be recognized that the copper contents of Dermaptera were higher than the other Orthopteroid insects and Dictyoptera were the lowest. Each values of them showed as follows: Dermaptera, Anisolabididae; 7.35-1,979 ppm, Labiduridae; 263-2,625 ppm, Apachyidae; 1,008, Chelisochidae; 457-858 ppm, Forficulidae (Anechurinae); 300-817 ppm, Forficulidae (Forficurinae); 252-1,606 ppm, Orthopteroid, Gryllidae; 423-930 ppm, Acrididae; 405-1,979, Dictyoptera, *P. americana* Linnaeus; whole body, 78-211 ppm, Head; 93-903 ppm, Wings; 140-739 ppm, Exoskeleton; 334-415 ppm, Eggs; 232 ppm.

#34

THE LIFE CYCLE AND GEOGRAPHICAL VARIATION ON THE MORPHOLOGY OF FORCEPS OF ADULT MALE *ANECHURA HARMANDI* (BURR) (FORFICULIDAE:DERMAPTERA). K. Terata and S. Sakai*, Institute of Biology and Life Sciences, Daito Bunka University, Takasaka, Saitama, Japan, 355.

Anechura harmandi (Burr) had an univoltine life cycle and eggs were reproduced in winter, January to April in Japan. After four moulting stages, winged adults were produced and till July, nymphs became adults. This species has hard cerci or forceps and the individual variation in length was wide. Though the short and long types were classified in forma *harmandi* and forma *lewisi*, respectively, the continuous intermediate type between them was confirmed at present. There was, also, variation in the thickness and the degree of curve or angle of forceps and the shorter the forceps were, the thicker and the smaller those angle was. From the observation on forceps at eight places in Japan, the geographical difference was found. Six populations to the east of the Lake of Biwa had two forma of *lewisi* and *harmandi* but the west two had not forma *harmandi*. Among east populations, there was variation in the ratio on the long-forceps type and the short one. Each population was reared in the laboratory and three generations were observed. The result indicated the similar tendency that the west populations did not produced the short-forceps type and each east one contained two forma as usual.

#35

HEMOLYMPHAL PROTEIN FRACTIONS ON DERMAPTERA

H.Koike and S.Sakai*, Department of Entomology, National Institute of Agroenvironmental Sciences, Tsukuba, Ibaragi and Institute of Biology and Life Sciences, Daito Bunka University, Takasaka, Saitama, Japan, 355

Biochemical systematics have important to ascertain the phylogenetic relations of Dermaptera as studied using HPLC: High performance liquid chromatography comparing with morphological results. The sensitive systems constructed 205 nm spectroscopy and Shim-Pack as separation column was used. In Anechurinae, Forficulidae, there are two forms of *Anechura* (*Odontopsalis*) *harmandi* Burr (1904). Macrolabial forma as *f. lewisi* and cyclolabial forma as *f. harmandi* have known to be observed the morphological difference of the forceps but the two forma were identical results in HPLC.

In molecular weight distribution, two types were recognized in the weight distribution for the Dermaptera insects used. Order in retention time was shifted in descending order as *Anisolabis maritima* (Bonelli) 1832 in Anisolabididae and *Labidura riparia japonica* (de Haan) 1842 in Labiduridae but in ascending order as *Euborellia annulipes* (Lucas) 1847 in Anisolabididae and *Forficula mikado* Burr, 1904 in Forficulidae. The retention time of the hemolymphal protein fractions on Dermaptera seems to be predicted the evolutionary phylogenetic relationships.

#36

CYTOTAXONOMIC STUDIES ON THE CHROMOSOMES OF THE DERMAPTERA WITH SPECIAL REFERENCE TO TWO CHELISOCHID SPECIES.

S.Sakai*, H.Hoshiba and M.Imanishi, Institute of Biology and Life Sciences, Daito Bunka University, Takasaka, Saitama, Japan 355.

The chromosomes of the Dermaptera seem to be generally holocentric whereas all the Orthopteroid insects have monocentric chromosomes. Dermaptera is characteristic in sex chromosomes; in males there are 4 types of XO, XY, XXY and XXXY and in females 3 types of XX, XXX and XXXX. The chromosomes of Dermaptera were claimed as the diffusion centromere, therefore, the karyotype analyses have been difficult in detail. The authors carried out C-banding analyses on some Japanese Dermaptera (Sakai, S. 1987: *Evolut. Biol. Orthopteroid insects* by B. Baccetti: 506-509).

In Chelisochid earwigs, Mittal and Suri (1981) reported firstly that *Proreus* sp. was 2n=16 with XY type of sex mechanism in the male. The authors carried out the second cytotoxic analysis in Chelisochid earwigs. Materials used were collected from Univ. Malaysia, Field Study Center on 14 March, 1986. Chromosome number of *Chelisoches morio* (Fabricius) 1775 was 2n=22 in the female oögonial somatic cells and *Chelisoches* sp. identified as *Chelisoches semirufus* Borelli 1926 was 2n=21 in the male meiotic and somatic cells. Their sex mechanism seems to be XXXX (female) and XXY (male). The more information of the Chromosomes will be reported.

#37

SYSTEMATICS IN BUMBLE BEES (HYMENOPTERA: APIDAE): CLADISTIC VERSUS ELECTROPHORETIC ANALYSIS. A. Scholl* and E. Obrecht, Institute of Zoology, Baltzerstrasse 3, CH - 3012 Berne / Switzerland.

Views on systematics and evolutionary history of bumble bees have been traditionally controversial. A recent cladistic analysis (Williams, 1985), based on male genitalia, suggests that the subgenera branched off more or less continuously. Early diverging subgenera are mainly those of the section *Odontobombus*, such as *Mucidobombus* (MC), *Megabombus* (MG), *Laesobombus* (LS), *Thoracobombus* (TH), *Fervidobombus* (FV), *Rhodobombus* (RH), and *Subterraneobombus* (ST), whereas most *Anodontobombus* such as *Pyrobombus* (PY) arose more recently.

Electrophoretic data would allow to test this hypothesis, since genetic divergence, which is estimated by this technique, is approximately proportional to the time of separation of evolutionary lineages. Our data show low levels of divergence if the subgenera MC, MG, LS, TH, FV, RH and ST are compared, but high levels if these are compared with PY. Furthermore, the level of divergence within PY is higher than between most of the other subgenera. We therefore conclude that PY branched off rather early, whereas the other subgenera are of more recent origin.

#38

BIOCHEMICAL SYSTEMATICS IN BUMBLE BEES: THE SUBGENUS PYROBOMBUS (HYMENOPTERA: APIDAE). A. Scholl*, E. Obrecht and R.W. Thorp, Institute of Zoology, Baltzerstrasse 3, CH-3012 Berne/Switzerland and Department of Entomology, University of California, Davis 95616, USA.

Enzyme electrophoresis was used to study genetic relationships of 10 Californian and 7 European *Pyrobombus* species. The Californian species have been divided into 3 groups (Thorp et al., 1983) according to the shapes of male sternites 8, gonostyli and penis valve apices. We have examined these characters in the European species. The European species can be assigned to group 3.

The electrophoretic data show that the species of group 1, *bifarius*, *huntii*, *vosnesenskii*, are genetically closely related. This is also found for the species of group 2, *caliginosus*, *centralis*, *flavifrons*, *vandykei*, whereas group 3 splits into 2 genetically highly differentiated subgroups. One of these contains the European *monticola* and *lapponicus*, which are close to the American *sylicola* and more distant to *edwardsii*, the other includes the American *mixtus*, close to the European *pratorum*, *pyrenaeus* and *hypnorum*, and more distant to *jonellus* and *cingulatus*. The data are discussed with respect to systematics and evolutionary history.

#39

PHYLOGENETIC RELATIONSHIPS AMONG MAJOR GROUPS OF TACHINIDAE (DIPTERA). H. Shima, Biological Laboratory, College of General Education, Kyushu University, Ropponmatsu, Fukuoka, 810 Japan.

Phylogenetic relationships were inferred for major groups of Tachinidae based on structure of the male and female genitalia and female ovipositing habits. There seem to be 2 major clades in the Tachinidae, each sister group of the other. One of them contains Phasiinae (including *Strongygaster*) and Dexiinae (including *Euthera*, *Dufouria* and *Imitomyia*): the former is primitive in retaining oviparous habit, extensively parasitizing heteropterous bugs except for *Strongygaster* that is an early derivative of this group; the latter has attained ovoviviparous habit in its early evolutionary period, except for its early derivatives, *Euthera*, *Dufouria* and *Imitomyia*, and is uniform well characterized by genital structure. The other clade contains Tachininae (including Palpostomatini and Ormiini) and Goniinae: both deviated from each other in rather recent time and there are not much differences in male genitalia among members of them; the former is characterized by ovoviviparous habit; the latter seems to be strongly diversified in rather recent time in getting ovoviviparous and micro-oviparous habits (some members even retain oviparous habit).

#40

DROSOPHILIDAE IN INDIA. O.P. Singh, Department of Zoology, School of Agricultural Sciences and Rural Development, North Eastern Hill University, Medziphema 797106 (Nagaland), India.

The Drosophilidae is a large family of small acalyptrate flies of world-wide distribution. India possesses a rich and at present little known fauna of *Drosophila* and allied genera of Drosophilidae. So far, about two hundred species representing nineteen genera of Drosophilidae have been reported from different parts of the Indian subcontinent. Of these, majority of the species (about 72%) belong to the genus *Drosophila* including its five subgenera namely *Dorsilopha*, *Drosophila*, *Hirtodrosophila*, *Scaptodrosophila* and *Sophophora*. The rest 28% of the reported species belong to eighteen allied genera of Drosophilidae.

Based on the results of studies, it appears that the members of the family Drosophilidae are fairly distributed throughout the Indian sub-continent. However, a vast area of great ecological interest is still unexplored and requires thorough investigation. The recent list of different species will be provided and discussed in the light of their habitat and geographical distribution.

#41

BIOSYSTEMATIC INFORMATION - FROM LINNAEUS TO THE 21st CENTURY. F. C. Thompson, Systematic Entomology Laboratory, U.S. Dept. Agriculture, Washington, D.C. 20560.

The content, format, and mode of distribution of Biosystematic Information have changed since 1758. What is Biosystematic Information? Who needs and wants it? And how to deliver it in the most efficient and timely manner? By integrating expert systems, relational database, image and compact-disc storage technologies, the Systematic Entomology Laboratory seeks to provide a revolutionary solution to these questions.

#42

SYSTEMATIC STUDY AND COMPARATIVE MORPHOLOGY OF THE GENUS ANTOCHA OSTEN SACKEN, 1859 (TIPULIDAE, DIPTERA) RECORDED FROM JAPAN, KOREA, SAGHALIEN AND KURILES, INCLUDING FOUR UNDESCRIBED SPECIES. Takashi Torii, Meikei High School, 1-1 Inarimae, Tsukuba-shi, Ibaraki Pref. Zip 305, Japan.

The genus *Antocha* is small to medium sized Tipulidae with wing length 3.5-14 mm, about 160 species are known of the world. In the present contribution, 16 already known and 4 undescribed species are discussed, with about 1,500 specimens examined including holotypes.

Following characters are mainly studied. [Male terminalia]: tip of outer gonostylus; setiferous lobe at basal-mesal part of gonocoxite; a pair of process on medio-caudal margin of tergite 9; caudal half of sternite 9; aedeagal sheath; tip of inner branch of parameres; tip of aedeagus; sperm duct in base of aedeagus. [Male legs]: setae of fore- and midlegs; length and thickness of hindlegs; spinules or setae of hindlegs; opposable tubercles at tips of femora and bases of tibiae of hindlegs. [Wing]: venation; macrotrichia distribution. [Female terminalia]: shape of cerci and hypogynial valves.

By the above characters, the 20 species of the genus *Antocha* discussed here are classified into several intra-generic groups. Additionally, new localities and first female records are given for several species.

#43

THE BIOGEOGRAPHY OF CORTICEUS IN THE UNITED STATES AND CANADA (COLEOPTERA: TENEBRIONIDAE). C. A. Triplehorn, Department of Entomology, 1735 Neil Avenue, The Ohio State University, Columbus, Ohio 43210

The distribution and tree host preference for the 13 species of *Corticeus* occurring in the United States and Canada is discussed. The association of species of *Corticeus* with various bark beetles (Scolytidae) remains unclear.

#44

ODONATE FOSSILS FROM THE LOWER CRETACEOUS OF NORTHEASTERN BRAZIL. Dennis C. Wighton, Department of Genetics, University of Alberta, Edmonton, Alberta, Canada T6G 2E9.

Two new species of fossil Anisoptera (dragonflies) are reported from the Crato member of the Lower Cretaceous (Aptian) Santana formation of Northeastern Brazil. One adult species is assigned to the extinct subfamily Aeschnidiinae, genus *Aeschnidiopsis* and suggests an original Pangaeaian distribution for the subfamily and a north and south polar division during Mesozoic times isolating the three generic populations. One larval species is assigned to the family Macromiidae, genus *Macromia* and represents a very primitive condition where large antennae may have played the major sensory role in detecting prey. The referred larva is the oldest member of the Macromiidae and the first macromiid from S. America. Other adult fossil zygopteran damselflies are also presented.

#45

THE DELPHACIDAE (HOMOPTERA) OF ALASKA. S. W. Wilson, Department of Biology, Central Missouri State University, Warrensburg, Missouri 64093.

Fourteen species of Delphacidae are recorded from Alaska. One new species of *Kusnezoviella* is described. *Acanthodelphax analis* (Crawford) and *Javasella arcanastyla* (Beamer) are new combinations.

Of the 14 species in 10 genera, 2 species are Holarctic in distribution, 1 is recorded only from Alaska, 3 are Nearctic, and 8 are Palearctic apparently having their distribution in Alaska restricted to north and west of the Brooks Range.

#46

SYSTEMATIC POSITION OF *HESPERENTOMON* AND *FUJIENTOMON* IN VIEW OF THE FINE STRUCTURE OF SPERMATOZOA AND PSEUDOCULI (PROTURA). W.Y. Yin, L. Xue and B. Tang, Shanghai Institute of Entomology, Academia Sinica, Shanghai 200025, China.

The genus *Fujientomon* was recognized in the past as a sister group with *Hesperentomon*, and both of them are intermediate forms along the evolutionary line from *Eosentomon* to Acerentomids. In our recent investigation, we found that the spermatozoa of *Hesperentomon* are spiral with acrosome and flagella, which have variable microtubular patterns: 12+0 to 9+0; while in *Fujientomon* the sperm is globular, without acrosome and axoneme. The fine structure of pseudoculus of *Hesperentomon* is similar to that of *Gracilentulus*, but each sensory cell send forth only 1 ciliary processes instead of 2. And in *Fujientomon* it is more or less resemble to that of *Sinentomon*.

Therefore, we suggest that the genus *Hesperentomon* may be the primitive group of Protura, and *Fujientomon* probably a rather specialized one.

#47

ON THE CLASSIFICATION OF SUBGENUS *LARROUSIUS* NITZULESCU, 1931 AND *PHLEBOTOMUS WUI* STAT. NOV (DIPTERA: PHLEBOTOMIDAE). Xiong Guang-hua, and Jing Chang-fa, Department of Vector Biology and Control, Institute of Parasitic Diseases, CAPM, 207 Rui Jin 2 Rd., Shanghai 200025, P.R. China.

The classification of subgenus *Larrousius* is discussed and the relative importance of their morphological characteristics compared. The authors stress that the most important taxonomic characteristic is the male aedeagus which varies with the species, while the morphology of the spermatheca segments and the pharyngeal armature are important for female taxonomy. Other morphological characteristics are either useless or of no importance for the classification of the subgenus *Larrousius*. *Phlebotomus major* Annandale, 1910 and *P. major wui* Yang et Xiong 1965 belonging to the subgenus *Larrousius*, are quite different in the morphological characteristics of the pharyngeal armature, spermatheca segments and aedeagus. Thus it is suggested by the authors that the subspecies *P. major wui* Yang et Xiong, should be raised to specific status.

#48

CONTRIBUTION TO THE STUDY OF THE IMMATURE FORMS OF THE GENUS *OXYAGRION* SELYS, 1876 WITH THE DESCRIPTION OF LARVA OF *OX. SANTOSI*, MARTINS, 1967 (ODONATA: COENAGRIONIDAE). J.M. Costa, Department of Entomology, Museu Nacional, Rio de Janeiro, Brazil.

This paper presents new information on the immature forms of the genus *Oxyagrion* Selys, 1876 (Odonata, Coenagrionidae). It contributes to the determination of primitive and derived characters (symplesiomorphies and synapomorphies respectively), needed for the study of the phylogenetic relations among the species of the genus. Of the eighteen described species in the Neotropical region, immature forms are known for eleven (cf. Santos, 1966; Bulla, 1973; Costa, 1979, 1981, 1986, 1987). *Oxyagrion santosi* was described by Martins (1967), based on some adults collected in São Paulo, Minas Gerais and Paraná (Brazil). Analysis of the morphological characters of both adults and immature forms shows that this species is close to *Ox. terminale* Selys, 1876 and *Ox. pavidum* Selys, 1876. However, the adults differ from *Ox. terminale* by the small pterostigma and short anal appendages, which are distally enlarged, and from *Ox. pavidum* by the presence of small projections at the extremities of the superior anal appendages, easily seen in profile. The immature forms differ from the other two species by having the tracheal gills not branched.

PROTHORACICOTROPIC HORMONES IN THE DEVELOPING SILKWORM EMBRYO, BOMBYX MORI. Hajime Fugo, Department of Sericulture, Tokyo University of Agriculture and Technology, Fuchu-shi, Tokyo 183, Japan.

At least three neurohormones are synthesized during the embryogenesis of the silkworm. In this symposium, we will mention the presence and fluctuation of the prothoracicotropic hormone (PTTH) activity during the embryonic development.

Although two distinct forms of PTTH are present in embryos, one is a PTTH for Samia which does not stimulate the prothoracic glands (PG) of Bombyx. The other is a PTTH for Bombyx and this one can stimulate the Bombyx PG. A PTTH for Bombyx seemed to be located at the head of the embryo. The first detectable activity of the PTTH was found in embryos which had developed almost to the stage of the differentiation of their neuroendocrine system.

The physiological significance of the PTTH is mere guesswork and whether the same concept of PTTH is applied to the embryogenesis as in the case of post-embryonic development of the insects is the subject for a future study.

CUTICULOGENESIS, ECDYSTEROID METABOLISM AND PTTH ACTIVITY IN THE EMBRYO OF MANDUCA SEXTA. S. Ziese*, A. Dorn, A. Lamer, Institut für Zoologie, Universität Mainz, D-6500 Mainz, Germany; L.I. Gilbert, Department of Biology, UNC, Chapel Hill, N.C. 27514, USA.

We attempted to correlate ecdysteroid metabolism and PTTH levels with cuticulogenesis in the Manduca embryo. Altogether 5 "cuticles" are deposited: 2 by the serosa (after 15h post oviposition = p.o. and 24h p.o.) and 3 by the embryo (after 44h p.o., 50h p.o. and 69h p.o.). Only the 1st serosal and 3rd embryonic (=larval) cuticles are lamellated like a true cuticle (the others are membrane-like), and only the deposition of these cuticles is accompanied by peaks of free ecdysteroids. Polar maternal conjugates (26-hydroxyecdysone-26-phosphate) are hydrolyzed a few hours after oviposition resulting in a maximum of free 26-hydroxyecdysone around 12h p.o., immediately before synthesis of the 1st serosal cuticle^{1,2}. Later its conversion leads to a peak of 20,26-dihydroxyecdysone which correlates with the formation of the 1st larval cuticle beginning after 69h p.o.^{1,2}. PTTH determinations in heads indicated high levels during late embryogenesis but also appreciable amounts during early embryonic development. These results suggest that neurohormones, ecdysteroids and juvenile hormones are not only involved in the insect post-embryonic development, but also in the regulation of developmental processes in the embryo.

¹Warren et al., 1986, J. Liquid Chromatog. 9, 1759.

²Dorn et al., 1987, Int. J. Invert. Reprod. Dev. 11, 137.

INTERACTION OF ECDYSTEROIDS AND JUVENILE HORMONE ON CUTICLE DEPOSITION DURING EMBRYONIC DEVELOPMENT IN SCHISTOCERCA GREGARIA (ORTHOPTERA). G. Sbrenna*, S. Scalia and A. Sbrenna-Micciarelli, Institute of Zoology, University of Ferrara, 44100 Ferrara, Italy.

Before hatching, at fixed developmental stages, the epidermis of S. gregaria embryo secretes three different cuticles: a first one, made of epicuticle only; a second one, the "embryonal", and the third, the "larval" one the insect hatches with. The depositions of second and third cuticle are correlated with hormonal pulses of free ecdysteroids.

"In vitro" explantations of isolated embryo abdomens (with and without yolk) show that both these cuticulogenes can take place in absence of cephalic neuroendocrine system (CNS) and that the ecdysteroid peaks are i) not due to "de novo" syntheses by prothoracic glands and ii) independent from CNS. The different ultrastructural organisation found in the third cuticle from cultured embryos could be ascribed to altered control of metabolic fluctuations, probably due to CNS absence.

In presence of exogenous 20-OH-ecdysone an anticipation of cuticle deposition is observed in the explanted abdomens, but cuticular successions and their time intervals do not change. JH III added both in presence and absence of the exogenous ecdysteroid modifies the ultrastructural organisation of "in vitro" secreted cuticles.

ECDYSTEROIDS IN ADULT AND EMBRYONIC DEVELOPMENT OF CRICKETS, GRYLLUS BIMACULATUS (ENSIFERA: GRYLLOIDAE). K.H.Hoffmann*, W.Espig and E.Thiry, Department of Zoology, University of Ulm, 7900 Ulm, FRG.

In a large variety of insect species it has been shown that ovaries of reproductively competent females not only contain ecdysteroids, but are capable of synthesizing these molecules. Ovaries from adult females of G. bimaculatus produce an average of 500 pg ecdysone equivalents per hour, in vitro. In ovariectomized females ecdysteroids are still present. Sections of the abdominal integument are shown to synthesize ecdysone de novo from cholesterol.

In many insect species maternal ecdysteroids are accumulated in a conjugated form and they are also present in newly laid eggs. In unfertilized eggs as well as in young embryos of G. bimaculatus only small amounts of ecdysteroids, free and conjugated, could be detected by a radioimmunoassay. In order to prove these remarkable results, we followed the transfer of radioactivity from the female into the eggs after feeding the females with ¹⁴C-cholesterol. Again, only small amounts of free and conjugated ecdysteroids were found during early embryogenesis. During late embryogenesis ecdysteroid titers rise dramatically. This increase seems to be due to a de novo synthesis by the embryonic endocrine system. Supported by the DFG (Ho 631/11-1).

BIOSYNTHESIS, METABOLISM AND FUNCTION OF JUVENILE HORMONE IN EMBRYONIC DEVELOPMENT OF THE COCKROACH NAUPHOETA CINEREA. C. Bürgin Grossniklaus, E. Brünig and B. Lanzrein Division of Animal Physiology, University of Berne, Berne, Switzerland

We shall present a review-type lecture. In this ovoviviparous species the eggs are packed after ovulation and fertilization into an egg-case which is retracted into the uterus of the female, where embryonic development (40 days) takes place. We have shown that corpora allata from embryos at stages after dorsal closure synthesize and release methyl farnesoate and juvenile hormone III (JH III) (Insect Biochem. 18:3-9, 1988) and that the titer of both reaches high values from dorsal closure until shortly before hatching (Int.J.Invert.Reprod.Devel.8:269-278, 1985). At the latter stage efficient degradation of JH III was seen to set in, whereas in earlier stages very little degradation was seen (Insect Biochem. 18:3-9, 1988). When the JH III titer was suppressed by application of ethoxy-precocene (EP) lack of larval characteristics of the cuticle and impaired differentiation of the midgut, among other effects, were observed. Application of JH III to EP-treated embryos was seen to restore, to some extent, the differentiation of the midgut (Int.J.Invert.Reprod.Devel.12:29-44, 1987). These data show that JH plays an important role in late embryonic development of Nauphoeta.

THE ROLE OF JUVENILE HORMONE IN LATE EMBRYOS OF LOCUSTS AND SOME OTHER INSECTS; FACTS AND QUESTIONS. M.P. Pener, Dept. of Zoology, The Hebrew University, Jerusalem 91904, Israel.

In eggs of Locusta migratoria a prominent juvenile hormone (JH) peak is observed on day 10 (about 82% of the duration of egg development), but within the next 2-3 days JH titre decreases and it is close to nought in hatchlings. Application of precocene III to 8-day-old eggs destroys the embryonic corpora allata and sharply reduces JH titre at day 10. Nevertheless, such embryos hatch normally and the resulting 1st- and 2nd-instar hoppers are morphogenetically normal; the earliest prothetelic disturbances become overt by death in the moult from the 2nd- to 3rd-instar, revealing 3rd-instar adultiforms. However the same disturbances are observed also after precocene treatment of the hatchlings which experience the JH peak on day 10 of egg development. Thus, the high JH titre in the late embryo does not affect early hopper development in Locusta. Experiments on some other species and a survey of the literature indicate a similar situation in some other insects too. Evidence in the literature that sole absence of JH in late embryos or early 1st-instar larvae induces prothetelic post-larval differentiation is scarce and it is not entirely conclusive. The role of the high JH titre in the late embryo is obscure, since the early larval development seems to be predetermined and independent of JH.

POSSIBLE IDENTITY BETWEEN SITES OF JUVENILE HORMONE (JH) AND CELL-CONTAINED IMMUNOREACTIVE MATERIAL RELATED TO THE JH-CARRIER-PROTEIN (JHC) IN *LOCUSTA MIGRATORIA*. R. Hartmann*, C. Jendrszok, Institute für Biologie I der Universität, Albertstrasse, 21a, D-7800 Freiburg (FRG).

The haemolymph of *Locusta migratoria* contains a glyco-lipo-protein (Mr: 480 KDa; IP: 6.8) which selectively binds 3H-JH3 (Kd: 2.6×10^{-8} M). Upon treatment with 8M urea, JHC-x-3H-JH3 dissociated into 80-KDa subunits (JHC-su), still bearing the tritiated JH3. Rabbit immunizations with purified JHC or JHC-su, yielded two monospecific antisera "anti-JHC and anti-JHC-su" (test for specificity by 2D immunoelectrophoresis & blotting techniques). Both antisera detected exclusively sites of JHC- or JHC-su-related immunoreactive material in different organs of adult locusts and in differentiating tissues during embryogenesis. Such material was detected in all the tissues known to react drastically upon JH-deficiency in adult locusts. These are the neurosecretory cells of the pars intercerebralis, the follicular cells of terminal oocytes, the epithelia of the spermatheca and of all the male accessory gland tubules. At 4-5 days of embryo-genesis, material related to JHC or JHC-su was detected in all ectoderm-derived tissues (foregut, hindgut, hypodermis, brain, ventral nerve cord, stomatogastric nervous system) and also in the serosa. From serosal cytosolic preparations a JH3-binding protein (Kd: 10^{-8} M; Mr: 240 KDa) could be separated by immunoadsorption, using immobilized anti-JHC or anti-JHC-su. Intact serosal epithelia produced JH3 in organ cultures by methylation of (10-3H)-JH3-acid to (10-3H)-JH3 and by incorporation of tritiated CH3 from 1-(methyl-3H)-methionine into the hormone. Thus anti-JHC-su might be used predominantly as an indirect tracer in future experiments to locate possible sites of JH.

GENITALIA IN DIPTERA, A MULTIPLE FUNCTIONAL SYSTEM.

C. Dahl, Dpt. of Zoology, Section of Entomology, Uppsala University, Box 561, S-751 22 Uppsala, Sweden
 Female and male genitalia in Diptera are the most well studied sources for taxonomic characters at different phylogenetic levels. Among the wealth of information on single characters exist several synoptic and/or phylogenetic studies, which offer hypotheses on the origin of and relations within most taxa. Phenotypic analyses have contributed valuable facts to such surveys. With increasing knowledge of the role of postembryonic organization, behaviour and chemo- and mechano-sensory languages, a more system orientated approach is needed. Different functional solutions exist for male copulation and sperm transmission units, which meet different solutions for sperm reception and fertilization in female units. To understand the existing diversity in dipteran male and female solutions, it becomes necessary to restudy the multiple functions of single units, the integrations within subsystems, and the cooperation between female and male subsystems with this new approach and with combining techniques from several fields. Some central problems are identified, which should come into focus for studies with new techniques and a multidimensional system analysis. By this homologies, convergences or parallelisms in body architecture and their values for functional solutions might be better understood.

FERTILIZATION STRATEGIES IN INSECTS. M. E. DEGRUGILLIER, USDA, ARS, Metabolism and Radiation Research Laboratory, State University Station, Fargo, ND 58105.

The fertilization process in insects is a rapid event that involves the precise placement of gametes so that sperm entry of the egg can occur. Various modifications of the female reproductive tract (i.e. valve-like structures, position of the spermathecal ducts, specialized fertilization chambers, etc.) as well as structural properties of the egg itself, have evolved to ensure that fertilization is successful. Although in many species the gametes reach the fertilization site principally by physical means, sperm entry of the egg tropyle appears to be mainly a biochemical event.

SPERMATOPHORE FORMATION AND INSIMATION IN GRASSHOPPERS.

D.W. Whitman, IBPMR-Lab, USDA-ARS, Tifton, GA 31793, USA
 The functional morphology of male and female grasshopper reproductive structures will be discussed as they relate to spermatophore formation, insimulation, and sexual selection. A unique copulatory mechanism in Romaliinae grasshoppers, which allows the passage of multiple spermatophores during a single mating, will be highlighted.

FEMALE INFLUENCE OVER SPERM TRANSFER AND PATERNITY IN THE FIELD CRICKET, *GRYLLUS BIMACULATUS* (DE GEER). L.W. Simmons, Department of Zoology, University of Liverpool, P.O. Box 147, Liverpool L69 3BX, U.K.

Female field crickets, *Gryllus bimaculatus*, show extensive multiple mating within and between males. Sperm are transferred after mating from an externally attached spermatophore. Female interference with insemination by premature removal of spermatophores, however, is well documented in orthoptera although the significance of such behaviour is unclear.

Behavioural observations suggested that females may adopt a strategy of post-copulatory mate choice based on a variety of male characters including body size and kinship. Females were shown to remove the spermatophores of those males rejected before sperm were transferred whilst allowing those of chosen males to remain attached. Furthermore, females repeatedly remated with chosen males. Since sperm displacement does not occur females accept large quantities of sperm from these males. Spermathecal morphology suggested that sperm should mix in storage and sperm competition experiments showed that the fertilization success of a male was dependent on the numerical representation of his sperm in the spermatheca.

Females may thus influence sperm competition and determine the paternity of their offspring, accepting large quantities of sperm from chosen males thereby diluting out the sperm stored from previous matings.

NATURAL SELECTION FOR ALLOMETRIC GROWTH. Bernard J. Crespi, Museum Of Zoology, University of Michigan, Ann Arbor, Michigan 48109-1079, USA.

Allometric growth is a result of either natural selection, constraints on development, or some combination of these two processes. This paper describes a statistical model, based on Sewall Wright's method of path analysis, for the measurement of directional and stabilizing selection on allometry and allometric growth. The model involves adjustment of each log-transformed measured character for the effects of an underlying general size factor, and inspection of the correlation coefficients between the size-adjusted characters, general size, and reproductive fitness. The signs and magnitudes of these selection coefficients, combined with biological insight, may reveal hypotheses of selection on the general and secondary size factors that are considered here as the true objects of selection. These hypotheses may subsequently be tested by measurement of additional characters and experiments designed to uncover the causes of selection. Through the analysis of stabilizing selection on size and shape allometry, the path model provides an explicit test of the hypothesis that allometry and allometric growth are the result of natural selection rather than developmental constraints. The path model was applied to two independently measured versions of Lande and Arnold's data on morphology and survivorship in a species of pentatomid bug. The two analyses suggested the hypothesis that bug survivorship reflected directional selection for wing loading, the allometric relationship between body weight and wing surface area.

ALLOMETRY IN SOME SCARABAEOIDEA: PATTERNS, FUNCTIONS AND EVOLUTIONARY IMPLICATIONS. H.F. Howden, Department of Biology, Carleton Univ., Ottawa, Canada K1S 5B6.

Allometry in horns and sometimes in elongated fore-legs occur sporadically throughout the Scarabaeoidea. Use of horns varies from genus to genus. Horns may be used for digging, bracing in the burrow, provisioning food, cleaning the body, fighting, or visually "increasing" the size. In species with pronounced male allometry, the larger "major" individuals are concentrated in favorable habitats. Major males appear to be better able to defend a feeding site, minor males are more mobile. If disruptive selection acts on intermediate forms then related species of different sizes should occur within a genus, as is seen in *Dynastes*. Allopatric speciation can also account for some of the differences in allometry within a genus, especially if smaller species occur in peripheral habitats.

ALLOMETRIC GROWTH: CONTRASTS AMONG LEAF-CHEWING INSECTS. E.A. Bernays, Division of Biological Control, University of California at Berkeley, 1050 San Pablo Avenue, Albany, CA. 94706, USA.

Comparisons among grasshoppers and caterpillars demonstrate that relative head size is determined largely by the need for mandible adductor muscles of different sizes. These muscles fill more than fifty percent of the head capsule and are most strongly developed in species feeding on hard or tough leaves. Thus grass-feeding species have relatively larger heads than species feeding on herbaceous dicots.

Changes in relative head size occur during development. These vary with taxa, food type and absolute body size achieved. The constraints in large species of caterpillars relate to exactly how leaf material is handled by the mandibles. Details of mandible structure and function are found to be important in the degree of allometry.

STATIC AND DYNAMIC VIEWS OF ALLOMETRY: FUNCTIONAL AND DEVELOPMENTAL PERSPECTIVES. Joel Kingsolver, Dept. of Zoology, University of Washington, Seattle WA 98195 USA. Allometry can arise as a consequence of developmental associations or of functional coadaptation among metric characters. Functional allometric relations are commonly viewed in terms of the maintenance of mechanical or physiological similarity among individuals or species; while allometric growth trajectories are viewed in terms of changes in the rate and timing of developmental events in different structures. Here I argue that such a static view of allometry may be misleading in understanding how developmental changes map onto size and shape, and how changes in allometry map onto functional change. I review studies using experimental perturbations of development, functional analyses of allometry, and mathematical models of development and pattern formation which suggest that a more dynamic view may be needed to understand the evolution of allometry. Examples from limb development in insects and vertebrates, aerodynamics of insect flight, and wing pigment pattern in butterflies are discussed.

ALLOMETRIC VARIATION IN THE ECTOPARASITE *CHRYSOMELOBIA LABIDOMERAE* (ACARI: PODAPOLIPIDAE): PARTITIONING BIOGEOGRAPHICAL AND HOST-RELATED INFLUENCES. M.A. Houck, Department of Ecology and Evolutionary Biology, University of Arizona, Tucson, Arizona 85721.

Ectoparasites experience two major evolutionary influences which are reflected in morphological differences among taxa: 1) environmental accommodation and 2) response to specific host-type. *Chrysomelobia labidomerae*, an ectoparasite of adult chrysomelid beetles, has a geographic range which includes most of Central and North America. Thirteen populations of *Chrysomelobia* were sampled from beetles within various diverse habitats in Mexico and the US. Mites were collected from 2 genera and 7 species of beetles over a diverse range of temperatures, altitudes, and moisture gradients. Within habitat collections were made from various species of chrysomelid hosts, as were collections from the same chrysomelid taxon in different localities. Multivariate morphometric analyses of size and shape were partitioned as to locality and host influences on form.

LEPIDOPTERAN WING MORPHOLOGY: THE MULTIVARIATE ANALYSIS OF SIZE, SHAPE, AND ALLOMETRIC SCALING. R. E. Strauss, Department of Ecology and Evolutionary Biology, University of Arizona, Tucson, Arizona 85721

Wing morphology has been a major focus in taxonomic and evolutionary studies of lepidopterans. However, general patterns of quantitative variation and diversification in wing sizes and shapes, and the factors underlying them, remain unexplored. A morphometric study of wing variation in the convergent heliconine and ithomine butterflies revealed remarkable similarities, both in their morphologies at a given size and in their patterns of allometry and variability. Allometric size variation accounts for more than 90% of total morphological variation in the two groups, resulting in considerable shape differences between small and large species. Allometry is thus the major constraining factor of wing shape. A strong trend of increasing interspecific variability from anterior to posterior along the wings is consistent with hypotheses of aerodynamic constraint. Wings and bodies represent classical morphological "character suites" in that they vary almost independently of one another.

INTRASPECIFIC AND INTERSPECIFIC VARIATION IN SIZE AND SHAPE OF HONEY BEES (HYMENOPTERA:APOIDEA). H.V. Daly, Department of Entomological Sciences, University of California, Berkeley, CA 94720.

Intraspecific variation of 25 morphometric characters was studied in Apis mellifera. Samples included introduced European and Africanized bees from throughout the Western Hemisphere as well as representatives of natural races in Europe and Africa. Ten workers from a colony were measured. Principal component and discriminant analyses of the original measurements and size-adjusted measurements will be discussed in the context of geographic variation and taxonomy. Feral European bees in California and Africanized bees in South and Central America exhibit geographic variation. Comparisons will be made with intraspecific geographic variation in Apis cerana and interspecific variation among Apis species.

The Evolution Of Insect Nervous Systems: Cellular, Developmental And Molecular Aspects

ARCHITECTONIC HOMOLOGIES IN THE NERVOUS SYSTEMS OF INSECTS AND CRAYFISH. E. M. Leise, Departments of Zoology and Otolaryngology, University of California, Davis, CA 95616.

Developmental and comparative neuroanatomical studies of insect nervous systems suggest that they are built around a standard ground plan. Investigations of orthopteran ganglia have revealed a layered array of longitudinal, vertical, and oblique axon tracts; commissures; and neuropil regions. The abdominal ganglia of crayfish contain a similar set of structures, but it was not known if any were true homologues of their insect counterparts.

Crayfish abdominal ganglia 1 - 5 send three pairs of nerves to peripheral targets. After identifying and filling individual neurons or backfilling motor and sensory branches of these nerves with one of three markers, we traced the central projections of the marked neurons through the ganglionic structures (Leise et al., 1986, 1987, *J. comp. Neurol.* 253:25-45 and 266:495-518). We recognized neuropils and tracts that are homologues of those in the insects. For example, sensory hair afferents ramify throughout a large ventral neuropil just as they do in locusts and crickets. We conclude that the architectonic framework that is basic to insect nervous systems is also found in crustaceans. The degree of commonality of this fundamental design among the arthropods and their phylogenetic allies remains to be determined.

THE INSECT BRAIN IS DIVIDED INTO TWO MAJOR PREORAL COMPONENTS, ONLY ONE OF WHICH IS ORGANIZED ACCORDING TO A SEGMENTAL GROUNDPLAN. Nicholas J. Strausfeld* and Jürgen J. Milde. Arizona Research Laboratories Division of Neurobiology, University of Arizona, Tucson, AZ 85721, U.S.A. and Zoologisches Institut der Universität zu Köln, D-5000 Köln 41, Weyertal 119, Federal Republic of Germany.

Comparative neuroanatomy of the insect brain distinguishes two characteristically different preoral brain organizations. 1) A posterior structure (deutocerebrum) receives sensory inputs from the head and is organized on the lines of a thoracic segmental ganglion supplying articulated appendages. Mechanosensory and visual afferents converge to a thoracic-like neuropil containing interganglionic interneurons (descending neurons), motor neurons, local interneurons, and heterolateral (commissural) interneurons. 2) An anterior structure (protocerebrum) receives no primary afferents and shares no affinities with segmental ganglia. It comprises complex neuropils of, and associated with, the central body and mushroom bodies and receives ascending interneurons from segmental ganglia and the deutocerebrum. A common destination in the brain for antennal and visual afferents fits well with studies by other authors on the development and clonal analysis of the insect embryo showing: 1) a common segmental origin for the eyes and antennae; 2) a preoral migration of a postoral segmental neuromere during embryogenesis; 3) atavistic or opportunistic transformations of the eyes and antennae into mesothoracic-like structures. Supported by NIH Grant No. R01 EY07151-01

SEGMENTAL ORGANISATION OF GANGLIA IN *THERMOBIA DOMESTICA* AND *ACHETA DOMESTICUS*: EVOLUTIONARY IMPLICATIONS. J.S. Edwards* and J.C. Callaway, Department of Zoology, University of Washington, Seattle, WA, 98195, USA.

Thermobia domestica, a thysanuran, is here considered as a representative of neural organisation in the pre-ptyergote stem insect and is compared with an orthopteran, *Acheta domesticus* as representative of Polyneoptera. Abdominal giant interneurons are closely comparable, both with respect to segmental distribution of somata, and tracts in which the axon lie. The segmental distribution of giant fibre somata in the terminal ganglion of *Thermobia* appears to include one more posterior segment than in *Acheta*. Distribution of neurons stained by antibodies to neuropeptide SCP_B similarly reveals a reduction of the number of cells. Thoracic segments of both species have a set of putatively homologous cells. These extend through abdominal segments in *Thermobia*, but are absent in all abdominal ganglia of *Acheta*. The prominent immunoreactive median nerve of *Acheta* is absent from *Thermobia*; instead apparently homologous clusters of neurons occupy paired lateral nerves. To the extent that these examples reflect evolutionary lineage, they imply reduction in cell number, and regional differentiation. Supported by NIH grant NB0777B.

A COMPARATIVE APPROACH TO THE EVOLUTION OF ORTHOPTEROID CERCAL RECEPTOR/GIANT INTERNEURON SYSTEMS. G.S. Boyan*, E.E. Ball and J.L.D. Williams. Molecular Neurobiology, Research School of Biological Sciences, Australian National University, Canberra, Australia.

ON THE EVOLUTION OF SPECIALIZED NEURONAL FORM: PHYLOGENETIC VARIATION IN CERVICAL GIANT AXONS OF FLIES (DIPTERA). David G. King, Department of Anatomy and Department of Zoology, Southern Illinois University, Carbondale, Illinois 62901, U.S.A.

The existence of individually differentiated neurons poses an interesting problem: How can genetic variation together with natural selection mold development to yield the specialized neuronal features underlying adaptively evolved behaviors? Specifically, what genetic and ontogenetic mechanisms regulate the unique functional characteristics of individual neurons?

The ascending and descending axon pathways which comprise the cervical connective of flies are arranged consistently from species to species. However, the number and size of individual axons in these pathways varies dramatically among species, as exemplified by differences in the presence or absence of uniquely differentiated giant axons in particular locations. Such diversity not only represents a convenient expression of neuronal specialization; it also demonstrates considerable freedom for the evolutionary (and hence genetic) determination of behaviorally significant characters at the level of individually identifiable single cells.

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NEURONAL PHYLOGENIES RELATED TO EVOLUTION OF LOCOMOTORY BEHAVIORS. Dorothy H. Paul, Department of Biology, University of Victoria, Victoria, B.C., Canada V8W 2Y2.

The patterns and principles of neural development seen in grasshoppers and fruitflies, animals which have acquired the status of model organisms for research in developmental neurobiology, provide a conceptual framework for understanding neurophylogeny in other arthropods who themselves are not readily amenable to developmental analyses. I will draw upon these patterns and principles to interpret some neuronal phylogenies in a cluster of decapod crustacean families with differing locomotory behaviors. The behaviors are variants of tailflipping, the most extreme (uropod beating in Hippidae) constituting a new behavior, and they are mediated by neuronal circuits which were probably becoming organized in Devonian crustaceans, if not earlier. From this still incomplete case history of neuronal evolution in a behaviorally defined neuronal system, I will select for discussion specific examples of phylogenetically conserved neurons and of both phylogenetic loss and acquisition of neurons, and suggest adaptive correlates of the resultant, altered neuronal networks.

The Evolution Of Insect Nervous Systems: Cellular, Developmental And Molecular Aspects

ON THE "FLIGHT" SYSTEM OF A FLIGHTLESS GRASSHOPPER.

E.A. Arbas, ARL Div. of Neurobiology, 611 Gould-Simpson Bldg., Univ. of Arizona, Tucson, AZ 85721, USA.

Important questions arise from the observation that closely related species often exhibit marked differences in their behavior resulting from evolutionary divergence. Are ancestral neurons and circuits retained unchanged, eliminated, or adapted to novel uses? What developmental and genetic mechanisms sculpt neuronal circuits as behavior evolves? Studies comparing grasshoppers capable of flight with secondarily flightless ones may contribute answers to some of these questions.

Comparisons of the flightless *Barytettix psolus* with locusts have shown that adult *B. psolus* lack hindwings, have vestigial forewings and have eliminated thoracic muscles specialized for flight in locusts. Yet, elements of the ancestral flight mechanism can be identified. Pterothoracic dorsal longitudinal (DL) muscles (powerstroke muscles in locust flight) differentiate and are innervated during development, then atrophy or degenerate (depending on segment) by adulthood. DL motoneurons persist in the adult CNS and retain presynaptic terminals opposite inappropriate targets in the periphery. Sensory neurons homologous to receptors of the locust wing hinge occupy hinge-less cuticle and show comparable projections in the CNS. The physiology of these neurons is under study.

DO CHANGES IN NEURONAL RECOGNITION MACROMOLECULES CONTRIBUTE TO SPECIATION? J.L. Denburg* and R.T. Caldwell, Biology Department, University of Iowa, Iowa City, Iowa 52242 USA

Changes in behavior are the driving force for speciation and evolutionary changes. These behavioral alterations may be produced by changes in the patterns of synaptic connections among a fixed number of cells within the nervous system. Changes in the chemical nature or distribution of molecules responsible for the specificity of the cell-cell recognition will cause changes in synaptic patterns and will therefore be the immediate cause of the behavioral changes. Consistent with these ideas are the observations reported here that monoclonal antibodies that bind to candidate recognition macromolecules show much greater species specificity than do antibodies that bind to molecules present in all neurons in the nervous system. A library of 46 monoclonal antibodies was produced that specifically binds to neurons in the cockroach, *Periplaneta americana*. These antibodies were screened for binding to the nervous system of 15 species of cockroach distributed among 4 families in the order Dictyoptera.

EVOLUTIONARY CHANGE IN DIPTERAN VISUAL SYSTEMS. S.R. Shaw, Psychology Dept., Dalhousie Univ., Halifax, N.S., Canada.

A profound lacuna exists in our knowledge of the ways in which the nervous system can be modified by evolution. At the cellular level, very little is known about what is responsible for differences in nervous system function between related taxa. In the peripheral visual system of "advanced" muscid flies, the first synaptic zone (lamina) contains 14 identified cell types. Homologues of most or all of these can be recognized, in some cases with modified branching patterns, even in "primitive" families that diverged >200 MYr ago (Stratiomyidae, Rhagionidae). In contrast to this remarkable stasis, at least some of the homologues from different families make altered synaptic connections. Examples have been found of deleted connections, of added partners at a multiple-contact synapse, and of partner substitution. The synaptic cytoarchitecture has also altered. A major avenue of neural evolutionary change within this insect Order appears to have been the formation of new synaptic connections between neuronal homologues, the archetypes of which have withstood erosion since at least the Triassic. Recordings from some of the cells aim to clarify whether synaptic reaffiliation represents a means to modify function, or whether common functions have emerged convergently, using differing synaptic connections in different taxa.

MECHANISMS OF SEGMENTATION OF INSECTS AND MYRIAPODS AND THEIR BEARING ON PHYLOGENY. A. Minelli, Department of Biology University of Padua, I 35131 Padua, Italy.

Our understanding of segmentation in tracheate arthropods mainly rests on recent research on *Drosophila* where experimental embryology has been coupled with molecular genetics.

New studies of segmentation in myriapods broadly agree with the models derived from *Drosophila* and suggest a general occurrence within tracheates of the following four-step process of segmentation: (a) biochemical marking of a few repetitive units, (b) interactive doubling of these primary units, endowing the embryo with an array of biochemical markings corresponding to the final number of segments, (c) more or less heterochronous transpatterning, stabilization and morphological expression of this "segmental" arrangement, (d) repatterning and development of tagmosis. These mechanisms are also possibly at work in crustaceans, but not in annelid worms, thus speaking in favour of the monophyly of arthropods and against a close relationship between annelids and arthropods.

FUNCTIONAL MORPHOLOGY AND EVOLUTION OF ANTENNAL CIRCULATORY ORGANS IN MYRIAPODS AND LOWER INSECTS. G. Pass, Institute of Zoology, University of Vienna, A-1090 Vienna, Austria.

A broad comparative investigation of the circulatory organs supplying the antennae in the lower Tracheata revealed an unexpected diversity in structure and function. All myriapods possess antennal vessels connected to the large dorsal vessel behind the brain. This connection is considered to be an ancestral state which was lost at the base of insect evolution. In insects separate antennal vessels with basal ampullae (rarely antennal diaphragms) are present which communicate with the frontal hemocoel. In some ancestral insect orders the ampullae are apparently not pulsatile. In most groups, however, muscles associated with the ampullae result in true forcing pumps ("antennal hearts"). These muscles differ widely in their attachments and act either as dilators or compressors of the ampullae; a derivation from pharynx dilators is strongly indicated.

LEG-BASED APPENDAGES OF CARBONIFEROUS INSECTS AND THEIR PROBABLE EQUIVALENTS IN RECENT EMBRYOS.

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Abdominal segments of juvenile Carboniferous insects often bear abdominal leglets (sometimes with double claws) and/or leg derived appendages (exites, endites). So far, leglets have been found in Archeognatha, Monura, Diaphanoptera, Megasecoptera, some Paleodictyoptera, Protodonata, undetermined Neoptera, and Endopterygota (eruciform-like larva of Mecoptera-Hymenopteroidea); leglets, coxal and trochanteral vesicles (endites) in Thysanura; and leglets and plate gills (exites) in Ephemeroptera and Paraleptoptera. Both insect nymphs and larvae are primitively polydipod. Rudiments of leglets and endites occur in recent endopterygote embryos. The ground-plan of the insects abdomen has a triangular sternum and 4 pairs of leg-derived appendages inserted by leg muscles. I suggest that leg-derived rudiments have the potential to reappear later in evolution in some endopterygote larvae.

INSECT REPRODUCTIVE SYSTEM AND EXTERNAL GENITALIA

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The arthropod celom is reduced to a metameric grid around the gut. Detached lateroventral parts form coxal (segmental) organs; remainder is reproductive, maximum tubules 5 dorsal+5 ventral longitudinal, 2 dorsal+1 ventral transverse, and 2 dorsoventral in each postcephalic somite. Efferent ducts are lateroventral from celomoducts (Arachnida, Diplopoda), composites from the dorsal grid (Crustacea, Insecta), or 2° off the ventral (Collembola, most Myriapoda). There is no significance to anterior or posterior gonopores, the presence on different somites showing precursors to higher taxa had multiple apertures, as still in Pycnogonida. In *Insecta*, 2 dorsal transverse members form 2 ovarioles bilaterally abdominal somite I-VI. The inner ends join dorsomesal longitudinal ducts (ovarian ligaments), the outer, dorsolateral (oviducts) exiting on VII. In *♂*, testes may be the grid generally (e.g. Plecoptera) as in most other arthropods, or just dorsal transverse members as in *♀* (e.g. Archeognatha). Dorsolateral ducts are wanting, the inner (vasa deferentia) exiting on X but reflexed to IX on the ventromesal longitudinal ducts. External genitalia are coxal+trochanteral endites (gonapophyses)+telopodites (styli) of abdominal appendages VIII, IX which were fully segmented leglets w/ungues in Paleozoic; *♂* Ephemeroptera had full complement of 8 endites, but only the 4 of IX served as penes; blind gonopores VII are present in some today. Archeognatha, Thysanura may retain trochanters VIII as well as coxendites, trochanters IX, but most *♂* have lost VIII. Trochanters VIII, IX form the ovipositor. Aptera (Diplura) *♀* gonopores are on VIII w/evidence of originally exerted gonopods, Protura are on XI through cercal endites, Collembola are on V w/ vestiges of exits on II as also in *♂* Archeognatha: Machilidae.

INSECT IMAGINAL DEVELOPMENT: A PHYLOGENETIC OVERVIEW

D.L. Cox-Foster, Department of Entomology, The Penn State University, University Park, PA 16802.

A wide diversity in imaginal development exists among insects in the types of morphogenetic movements, the imaginal cell location and morphology, and the participation of "imaginal discs" in insect metamorphosis. Several concurrent themes underlie this diversity beginning with the Apterygotes and spanning through the hemimetabolous to the holometabolous orders. Extensive review of the literature reveals the possible convergence and polyphyletic origins of holometabolous metamorphosis. This data will be related to the current information available on the organization of homeotic genes among different insects.

OVARIAN DEVELOPMENT AND PHYLOGENY AMONG PARANEOPTERANS. J. Büning*, Institute of Zoology I, University of Erlangen, D-8520 Erlangen, F.R.G.

The paraneopterans include the orders of Hemiptera, Thysanoptera, Phthiraptera, Psocoptera, and possibly the Zoraptera (with uncertain ovary structure). All types of ovaries (panoistic, polytrophic and telotrophic meroistic) are found. We ask: Is it possible to build a cladogram which is concordant with the widely accepted phylogram of the paraneopterans (Hennig, Kristensen)? We suppose, at the base of Paraneoptera/Holometabola, the "basic"-type of the polytrophic meroistic ovary has been developed. Synapomorphic characters: The polyfusome, the rosette formation, the oocyte determination (only one of the two oldest, central cystocytes will develop as oocyte). The 2ⁿ-rule is at least in part plesiomorphic. All these characters are found in Psocoptera/Phthiraptera (sister groups). In hemipterans, oocyte determination has changed: Only one cluster exists in each ovariole and up to 50 % of cystocytes are oocytes. A telotrophic ovary is the imperative consequence. In the Thysanoptera, the sister group of Hemiptera, more than one cluster exists, however 100 % of cystoblasts develop as oocytes. The cystocytes detach from one another after cluster formation and a secondary panoistic ovary is born.

RECAPITULATIONS IN HOLOMETABOLAN MORPHOGENESIS.

A.L. Tichomirova, A.P. Rasnitsyn*, Paleontological Institute, Acad. Sci. USSR, 117868 Moscow, USSR. Study of the late embryonal and postembryonal insect development revealed a general morphogenetic pathway similar in all examined insects (various beetles, *Musca*, *Dolichovespula*, *Acheta*). This basic similarity is obscured, the particular morphogenetic stages being exposed in active ontogenetic phases (larva, nymph, imago) of some insects and concealed in resting phases (egg, prepupa, pupa) of others. For instance, late embryogenesis of *Silpha* (Silphidae) and *Aleochara* (Staphylinidae) recapitulates a bruchid-like larva, an embryo of *Philonthus* (Staphylinidae) recapitulates both bruchid-like and *Silpha*-(*Aleochara*)-like larvae, and embryonal *Pterostichus* (Carabidae) passes through the stages corresponding to larvae of each Bruchidae, *Silpha* and *Philonthus*. Late prepupa and early pupa of *Dolichovespula* (Vespidae) correspond morphologically to an imaginal saw-fly because of sessile abdomen with exposed apical segments and genitalia, two-spurred fore tibia, fore wings with veins SC and 2A, head with true occipital suture (persisted as subocular grooves in imaginal head) and many other ancestral features.

PANBIOGEOGRAPHIC IMPLICATIONS FOR A PRE-CRETACEOUS ORIGIN OF LEPIDOPTERA-ANGIOSPERM HOST-PLANT RELATIONSHIPS. J. R. GREHAN, 47 Dover Road, Wainuiomata, New Zealand.

The evolution of modern Lepidoptera-angiosperm host-plant relationships in space/time is examined from a pan-biogeographic perspective. Lepidopteran and angiosperm distributions conform to standard global biogeographic patterns where the world's ocean basins represent the major natural biogeographic regions. The correlation of tectonic history with Lepidopteran and angiosperm evolution suggests that many of the modern insect and plant lineages (family and genus) were already differentiated by the beginning of the Cretaceous. The co-evolutionary implications of Lepidoptera-angiosperm biogeography are discussed in relation to fossil records.

THE REGULATION OF HORMONE SYNTHESIS IN INSECTS AND CRUSTACEA. Hans Laufer, The Department of Molecular and Cell Biology, The University of Connecticut, Storrs, Connecticut 06268, USA.

The corpus allatum (CA) of insects produces juvenile hormone (JH) which regulates reproductive functions in adults. The production of JH is controlled by allatotropins and allatostatins, neuropeptides from the brain-corpus cardiacum complex. We investigated the possible existence of JHs in crustacea and have found that crustacea possess methyl farnesoate (MF), an unepoxidated JHIII in their blood. The mandibular organs (MOs), structures homologous to insect CAs, synthesize MF in vitro (Laufer et al., 1987, Science 235:202). The greatest synthesis of MF by adult female MOs from the spider crab *Libinia emarginata* coincided with active vitellogenesis, suggesting that MF may act in crustacea as JH acts in insect reproduction.

MF synthesis and reproduction in crustacea appear to be controlled by the eyestalks. Removal of eyestalks enhances reproduction and doubles MF production by the MOs. Eyestalk extracts inhibit MF synthesis in vitro as does the synthetic peptide, pigment dispersing hormone (PDH) at 10^{-7} M. Red pigment concentrating hormone (RPCH), an octapeptide, at 10^{-6} M doubles MF synthesis by the MO. Since analogs to these crustacea hormones exist in insects, it may be possible that these peptides or molecules similar in structure play a role in regulating CA activity.

EVOLUTION OF COMPOSITION & FUNCTION OF INSECT SERUM STORAGE PROTEINS. J.G. Kunkel, Zoology Department, Univ of Massachusetts, Amherst, MA 01003, USA.

The hexameric serum proteins take on several roles in arthropods. Although storage may be one of their most important roles, we must explore the possibility that evolution has used them in other ways. Principal components analysis and tree building with amino acid compositions for 36 insect and 12 other arthropod hexamerins allow us to discriminate membership in several distinct clusters of hexamerins: one or two Arylphorin (Ap) clusters, a Female Specific Storage Protein (FSP) and Hemocyanin (HbCy). Two distinct Ap like proteins exist in both Dipterans and Dictyopterans with different developmental patterns; they are presumed to have distinct functions. The major correlation that has been observed is with molting in the hemimetabola and metamorphosis in the holometabola. Yet hexamerins are known which persist into the adult stage in the hemimetabola. An insectan HbCy has been recognized in a lepidopteran. Is this a relict of the evolutionary relationship to crustacean HbCy? The binding of insecticides observed in lepidopteran Ap may be an indication of a more general role of Ap as a carrier of compounds in the blood particularly during the molting and metamorphic phases of insect development. For instance a potential glycine carrier function for AP may be associated with silk production in Lepidoptera. Lack of FSP in some lepidoptera may force other hexamerins to take up the FSP function.

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LIPOPROTEINS AS CHARACTERS FOR THE STUDY OF ARTHROPOD PHYLOGENY Norbert H. Haunerland and William S. Bowers, Department of Entomology, The University of Arizona, Tucson, AZ 85721, USA

Lipid transport by lipoproteins is an essential but complex task in all living organisms. Since lipoproteins provide functional rather than morphological information, they seem particularly suited to evolutionary and phylogenetic studies. All insect lipophorins appear to share the same properties. Our recent investigations have focused on the lipoproteins of a wide variety of arthropods. We find that Millipedes (*Orthoporus ornatus*) and centipedes (*Scolopendra heros*), which are classified with insects in the same arthropod subphylum, also possess lipophorins very similar to those of insects. In contrast, a different lipoprotein is found in both terrestrial and aquatic members of the arthropod subphylum Crustacea. Surprisingly, arachnids, which are considered to occupy a phyletic status distant from both insects and crustaceans, use lipoproteins very similar to insect lipophorins. Species investigated include several members of the order Araneae (tarantula, *Eurypelma californicum*, crab spider, *Olios fasciculatus*, black widow, *Latrodectus hesperus*), Solpugidae (wind scorpion, *Eremobates* sp.), and Scorpiones (*Hadrurus arizonensis*). Interestingly, we discovered that members of the arachnid order Acari (mites, *Dinothrombium pandorae*) possess a lipoprotein, which appears similar to the crustacean particle. While these data are not in full agreement with current phylogenetic theories, our findings should encourage study of other functional biochemical characters appropriate to the investigation of phylogenetic relationships, perhaps including proteins linked to developmental processes.

ADAPTATIONS OF POST-EMBRYONIC STAGES IN THE EVOLUTION OF MAYFLIES, ESPECIALLY REGARDING THE SUBIMAGO. W.P. McCafferty and G.F. Edmunds Jr. (USA).

No Abstract

GEOGRAPHIC VARIATION IN INCIDENCE OF PUPAL DIAPAUSE IN ASIAN AND OCEANIAN SPECIES OF SARCOPHAGID FLIES. H. Kurahashi and T. Ohtaki*, Department of Medical Entomology National Institute of Health, Tokyo 141 and Department of Biology, Kanazawa University, Kanazawa 920, Japan.

The incidence of pupal diapause of 9 species in the genus *Boettcherisca* was studied in colonies collected from various localities in Asia and Oceanian islands. Colonies of *B. septentrionalis*, *B. nathani* and *B. peregrina* obtained from temperate regions of Asia and those of *B. formosensis* and *B. peregrina* from the continental subtropics entered pupal diapause in response to certain photoperiodic conditions at 20°C. In contrast, no distinct diapause was observed in other five species, *B. karnyi*, *B. koimani*, *B. timorensis*, *B. javanica* and *B. invaria*, which are indigenous to the tropical or subtropical habitats. The incidence of pupal diapause showed a geographic gradient in *B. peregrina* colonies originated from different climatic regions. Pupal diapause in *Boettcherisca* seems to have developed independently by the advancement of ecophysiological mechanisms which made those species capable of expanding their habitat from the tropical to temperate region.

IMPORTANCE OF SOME ADAPTATIONS (REPRODUCTIVE OR QUIESCENCE DIAPAUSE) IN THE LIFE CYCLE OF BRUCHIDAE (COLEOPTERA): THEIR IMPORTANCE IN PHYLOGENY. J. Huignard (France)

No Abstract

THE SYNAPTIC ORGANIZATION OF THE *DROSOPHILA* BODYWALL MUSCULATURE. H. Keshishian*, J. Johansen, M. Halpern, C. Chien, and M. Anderson. Biology Dept. Yale Univ. New Haven, CT. 06511 USA.

The *Drosophila melanogaster* larval and embryonic bodywall consists of singly identifiable segmental muscle fibers arrayed in hemisegment specific patterns of up to 31 fibers. Using immunocytochemical and physiological methods we have studied the synaptic phenotypes and the development of the neuromuscular synapses, and applied genetic methods to manipulate them. Glutamate, proctolin and octopamine-like neurotransmitter phenotypes were examined. Light and EM immunocytochemistry indicate each fiber receives up to two glutamate immunoreactive endings, with antibody staining localized to synaptic vesicles in the boutons. On a fiber specific basis the endings are highly stereotyped, with respect to 1) the details of branch arborization, 2) the region on the muscle fiber plasma membrane innervated, and 3) the bouton size distribution. Ionophoretic mapping shows that glutamate receptor distribution precisely matches the ending anatomy. In addition to structural stereotypy, there is also neurochemical stereotypy, governing which fibers receive proctolinergic and octopamine like immunoreactive synapses. Using homeotic transformants we have successfully changed the distribution of proctolinergic synapses within and between segments.

DEVELOPMENT OF THE *DROSOPHILA* NEUROMUSCULAR JUNCTION IN VITRO. K. Ikeda* and J.H. Koenig, Div. of Neurosciences, Beckman Research Institute of the City of Hope, Duarte, California, U.S.A.

The primary culture of neurons and muscles from the embryo of *Drosophila melanogaster* offers various advantages, e.g., (1) developmental steps from undifferentiated precursor cells to mature cells can be studied, (2) the genetic determination of differentiation can be studied using various genetic techniques, (3) the in vitro situation allows continuous light microscopic observation followed by physiological and electronmicroscopic investigations.

Newly deposited eggs are allowed to develop for two hours in order to reach the late blastula stage. Collected eggs at this stage are decholinized and dissociated in the culture medium and then plated onto culture dishes. When the cells are kept at 26°C, the first light microscopically observable sign of neuronal differentiation appears after about 30 min. This is the extension of radiopodia, which are thin, straight filaments specific to neurons. Axonal growth cones extend from the somata after 1 to 5 hrs and innervate cultured muscles. Between 5 to 12 hours, matured neuromuscular junctions are established. This developmental process will be shown electronmicroscopically. Support: NIH, NS18858.

ORIGIN AND EARLY DEVELOPMENT OF THE DORSOVENTRAL FIBRILLAR FLIGHT MUSCLES OF *CHIRONOMUS* (DIPTERA, NEMATOCERA). M.C. Lebart-Pédebas, Laboratoire de Cytologie, UA 1199 CNRS, Univ. P. et M. Curie, 7 quai St Bernard, 75252 Paris Cedex 05, France.

The flight muscles of all Diptera are formed of dorsolongitudinal muscles and dorsoventral muscles. Since in the adult these two groups of muscles are morphologically, functionally and biochemically identical, the question arises if they both develop from the same kind of Anlagen. Although the dorsolongitudinal Anlagen is well analyzed, little is known about the dorsoventral one. It is not known whether the dorsoventral group develops only from myoblasts or from preexisting larval muscles in conjunction with myoblasts, like the dorsolongitudinal muscles. Electron microscopy was used to analyse the dorso ventral group. The results showed that in *Chironomus* there is a larval muscle precursor of the dorsoventral flight muscle located in the mesothorax near the imaginal discs. This larval muscle consists of an unusual kind of muscle, shaped like a hollow tube. Inside this tube there are free myoblasts, axons and tracheae. At the beginning of the last larval instar this larval muscle splits to form 9 fibres. Later, the larval myofilaments disappear from the sarcoplasm thus forming 9 dedifferentiated muscle columns. The number of myoblasts increases considerably by mitosis and fusion occurs between the myoblasts and the columns. Each of the 9 columns corresponds to one imaginal muscle producing 5 tergopleural muscles, 2 tergosternal muscles and 2 tergocoxal muscles. In conclusion the results show that the dorsoventral and the dorsolongitudinal flight muscles arise from the same kind of Anlagen and follow a similar development.

GLUTAMATE RECEPTORS IN INSECT MUSCLE DURING METAMORPHOSIS. M. Saito, Jerry Lewis Center, UCLA, School of Medicine, Los Angeles, California, 90024.

Very few studies on the developmental changes of the glutamate receptor characteristics in insect neuromuscular junction have been reported. It is interesting to compare the glutamate channels on larval abdominal muscle and on adult thoracic muscle in *Tenbrio molitor* since in the pupal period most of larval muscle degenerate and are replaced by adult muscle.

Bath applied glutamate produced depolarization of the postsynaptic membrane of larval muscle whereas in adult muscle glutamate produced both depolarization and hyperpolarization. We compared the single channel properties of glutamate receptor channels in both stages. Single channels in the larval muscle had small conductance and long open time, whereas channels in the adult had large conductance and short open time. The reciprocal of channel close time was linearly related to the glutamate concentration in adult muscle. However channels in larval muscle showed a weak dependence on the glutamate concentration.

FORMATION OF ADULT MOTOR SYSTEM COMPONENTS IN *DROSOPHILA* DURING METAMORPHOSIS. W.J. Costello* and M. R. Hummon. Basic Sciences/COM and Dept. of Zool. & Biomed. Sci., Ohio University, Athens, OH 45701 USA.

In *Drosophila melanogaster* we are studying formation of the giant fiber pathway (GFP) during metamorphosis. A giant axon (GF) synapses first with an interneuron (PSI) and then with the jump muscle motoneuron (TTMn). TTMn and PSI exit the thoracic ganglion in a peripheral nerve (PDMN); PSI synapses onto the 5 motor axons within the PDMN which innervate the wing depressor muscle (DLM). To determine the timetable of GFP formation, we are using wild-type flies and a temperature-sensitive mutant, *shibire*, which affects receptor-mediated endocytotic processes.

In the thoracic ganglion, connectivity can be disrupted (indicative of critical periods) between GF: PSI @ <12h (white prepupa=Oh, @25°C); between GF: TTMn @ <36h; between PSI:DLM motor axons @ 12-44 h. A single larval nerve, 2nd thoracic (t2), gives rise to the adult nerve, PDMN, as well as another peripheral nerve containing wing elevator motor axons, the ADMN. The DLM is formed in early pupal stages by migration of adult myocytes along part of t2 to 3 larval fibers; each larval fiber is split to form substrates for the 6 DLM fibers. Such splitting is prevented, resulting in 3 fibers, if endocytosis is disrupted @12h; deletion of entire DLM fibers occurs if endocytosis is disrupted @20h. Functional motor activation of the DLM and TTM occurs by 72h; GFP activation doesn't occur until 84h.

A common factor causing these disruptions in development is prevention of receptor-mediated endocytosis, suggesting this process is critical for connectivity, pathfinding, myogenesis, and boundary formation.

METAMORPHOSIS OF LEGS AND LEG CIRCUITRY IN THE MOTH *MANDUCA* *SEXTA*. K.S. Kent* and R.B. Levine, ARL Division of Neurobiol., University of Arizona, Tucson, AZ 85721

During metamorphosis of the moth *Manduca sexta*, the larval thoracic legs are replaced by adult legs of very different form and function. The tiny larval legs are capable of lateral extension and medial flexion, allowing them to grasp the substrate as the animal crawls. At the end of larval life, the legs along with their associated sensory organs and muscles degenerate, and new adult legs develop. The adult legs are much larger than the larval legs and articulate such that they are capable of independent movement in several directions and walking with an alternating gait. This change in form and function is accompanied by a reorganization of the neural circuits controlling leg movements. We have identified leg motor neurons innervating the prothoracic legs of larval and adult *Manduca*, and using persistent fluorescent dyes we have been able to discover the fate of individual larval leg motor neurons. Our results suggest that larval leg motor neurons persist to innervate the new adult leg muscles, that they undergo significant remodeling of dendritic branching patterns, and that they innervate corresponding muscles at both stages.

ULTRASTRUCTURAL CHANGES IN MESOTHORACIC MUSCLES AND THEIR INNERVATION ASSOCIATED WITH PRE-METAMORPHIC DEGENERATION IN *MANDUCA SEXTA*. M. B. Rheuben* and P. J. Schaner, Department of Anatomy, Michigan State University, East Lansing, Michigan 48824, U.S.A.

In 5th instar larvae and early pupae, specific muscles and their innervation are remodeled during formation of the adult mesothoracic dorsal longitudinal flight muscle. The precise timetable of degenerative changes is specific to each larval muscle. A succession of cell types is associated with the muscle fibers, beginning with numerous fibroblasts beneath the basal lamina in 5th instars, phagocytic cells in prepupae and pupae, and myoblasts in the pupae. Decrease in muscle mass and the appearance of lipid (?) droplets apparently exocytosing from the sarcoplasm precede failure of the fiber's ability to contract by several days. The glial cells at the neuromuscular junction appear to withdraw the smaller cytoplasmic processes surrounding the nerve terminal and consolidate their cytoplasm. Relative numbers of disorganized active zones increase well before observable decline in synaptic transmission. The motor nerve often fails to conduct impulses before evidence is seen for final decline in the ability of the neuromuscular junction to release transmitter, and is correlated with changes in its glial sheath.

PATHFINDING BY MOTOR AXONS IN THE LOCUST EMBRYO. P.M. Whittington*, C.M. Myers and E.E. Ball. Department of Zoology, University of New England, Armidale, N.S.W., Australia 2351 and Research School of Biological Sciences, Australian National University, Canberra, A.C.T., Australia 2601.

To elucidate the mechanisms by which motor axons in the locust embryo are guided to their target muscles, we have described the spatio-temporal pattern of axon growth from identified motoneurons in thoracic segments from the earliest stages of outgrowth. The earliest motor axons to leave the central nervous system initially grow laterally in a parallel bundle beneath the dorsal basal lamina, then diverge at the edge of the developing ganglion into either of two pathways, corresponding to nerve root 3 or nerve root 5. Individual motoneuron growth cones contact both the nerve 3 and the nerve 5 routes with their filopodia yet axons reliably grown down only one or other of these routes. As a motor axon advances into the periphery it either navigates over axon-less stretches of the limb bud epithelium or fasciculates with pre-existing axon bundles. At particular points a given axon departs from its prior trajectory to follow a different axon bundle or epithelial pathway. We have identified the series of pathway choices made by the motoneurons which innervate the extensor tibiae muscle. These motor axons often make "errors" at choice points, growing down routes which lead both away from as well as towards the extensor tibiae muscle. The inappropriate axon collaterals, which may reach lengths of 100 μ m are withdrawn as the axon advances towards the target muscle.

NEUROMUSCULAR DEVELOPMENT IN THE ORTHOPTEROID INSECTS.

E.E. Ball* and J.M.A. Quinn, Molecular Neurobiology Group, Research School of Biological Sciences, Australian National University, P.O. Box 475, Canberra, A.C.T. 2601, Australia

Two questions arising from our previous work will be discussed. First, what is the phylogenetic distribution of muscle pioneers in arthropods? To answer this question we applied two monoclonal antibodies specific to muscle pioneers in *Schistocerca* to several ages of embryos of a wide variety of hemimetabolous and holometabolous insects. Of the species tested acridid grasshoppers, but only acridid grasshoppers, had muscle pioneer antigens recognized by the two antibodies. However, histological sectioning indicated the presence of muscle pioneers in all of the other orthopteroidean species examined.

Second, we have previously described the innervation of locust coxal muscle 133a at the light microscope level (J. Neurosci. 5:1808-1819) and how the filopodia of the first motor neuron to arrive, D_f, surround the 133a muscle pioneer and its associated mesoderm cells. Using serial electron microscopy we find that the growth cones of D_f and D_s (the next motor neuron to arrive) reach the mesoderm cells surrounding the 133a muscle pioneer but that few, if any, filopodia contact the muscle pioneer. The growth cones apparently wait until the mesoderm cells have fused with the muscle pioneer before making contact with the muscle.

LATE DEVELOPMENT OF CRICKET FLIGHT MUSCLE. A. Novicki*, R.K. Josephson, Dept. of Psychobiology, University of California, Irvine, CA 92717.

The metathoracic dorsal longitudinal muscle of the cricket *Teleogryllus oceanicus* differentiates and develops rapidly over the last nymphal instar. Within eight days, the muscle mass increases by a factor of 15, and fiber cross sectional area increases 6 times. During this period, the relative volume of mitochondria quadruples while the relative amounts of myofibril and sarcoplasmic reticulum decrease. Tracheoblasts begin to invade the muscle fibers immediately before the adult molt. Muscle mass continues to increase through four days after the adult molt, but the relative volumes of the components do not change. In some animals, the flight muscles begin to degenerate as early as eight days after reaching adulthood.

When the muscle is denervated immediately following the penultimate molt and examined 8 days later, the muscle mass and fiber cross-sectional area are significantly smaller than the innervated contralateral muscles. Despite the absence of neural input, mitochondrial content increases greatly and tracheoblasts invaginate into muscle fibers.

TRANSNEURONAL INDUCTION OF MUSCLE ATROPHY IN ADULT GRASSHOPPERS. EA Arbas, ARL Div. of Neurobiology, 611 Gould-Simpson Bldg. Univ. of Arizona, Tucson, AZ, 85721, USA.

Tergocoxal muscles of adult grasshoppers undergo significant atrophy after hindlimb autotomy. Autotomy occurs between the trochanter and femur and causes severing of the leg nerve (N5) but neither damages nor denervates the tergocoxal muscles. Atrophy begins in 7-10 days after autotomy and is complete by about 30 days with certain muscles being reduced in mass to 10-15% of control levels. Atrophy is restricted to the side and body segment where autotomy occurs. Autotomy severs N5, reduces load on the coxal muscles, and alters coxal use, possibly by changes in motor outflow. We tested the contributions of these influences on muscle atrophy by: 1) cutting N5 near the metathoracic ganglion without inducing autotomy, 2) re-loading coxal muscles following autotomy by gluing the leg back into its natural position, 3) inducing abnormal use of the coxa by tenotomy of the extensor tibiae muscle. All treatments severing N5 caused atrophy. Re-loading the muscles did not significantly prevent atrophy. We conclude that peripheral severing of N5 during autotomy is the primary cause of atrophy. Neurons projecting in N5 must thus affect CNS neurons that independently innervate coxal muscles and, through them, induce atrophy. Supported in part by: BRSG S07 RR07002 & a grant from the Univ. of Arizona Foundation.

RELATIONSHIP BETWEEN METABOLIC RATE, OXYGEN FREE RADICALS AND AGING. R.S. Sohal, Department of Biological Sciences, Southern Methodist University, Dallas, Texas 75275, U.S.A.

Results of a series of studies on the adult male housefly suggest that oxidative stress plays a causal role in the aging process. Experimental regimes that result in an increase in the level of physical activity or metabolic rate tend to shorten life span of the insects and vice versa. During aging as well as in response to elevation in metabolic rate, there is an increase in the rate of superoxide radical generation as well as in the steady state levels of molecular products of free radical reactions, e.g., H_2O_2 , oxidized glutathione, TBA-reactive material, n -pentane exhalation and lipofuscin. Activities of superoxide dismutase and catalase and concentration of reduced glutathione decreases during aging. Our recent studies on liver submitochondrial particles from mammals such as mouse, rat, guinea pig, rabbit, pig and cow also indicate an inverse correlation between species-specific longevity and rate of superoxide radical generation. It is postulated that progressive oxidative stress is a causal factor in the aging process.

ENERGY DISTRIBUTION, AGING AND METABOLIC RHYTHMS IN INSECTS. K.-G. Collatz, Institut für Biologie I (Zoologie), Universität Freiburg, 7800 Freiburg i. Br., Albertstraße 21a, FRG.

The allocation of energy resources among reproductive demands and other vital functions during an insect's life is life span determining. This quantitative relationship has been shown in several insect species, mainly in dipterans. It can explain on the ultimate level the differently evolved aging strategies of insects as ecophysiological adaptations. In blowflies, provision with protein (as a stimulant for egg development) and the opportunity to mate have profound influence on flight and nutritional behavior. They lead to different energy expenditures, especially due to activity metabolism, over the whole life span. The energy metabolism itself is in all these cases subjected to a sex and age dependent day-night-rhythm, whose persistence under constant light conditions indicates its endogenous nature. Evidence exists, that a glycolytic oscillator might play a role in the maintenance of such rhythms and therefore in the allocation of energy. This aging behavior is under investigation.

THE GENETICS OF LONGEVITY AND ITS PLEIOTROPIC LIFE HISTORY CHARACTERS IN *DROSOPHILA MELANOGASTER*. L.S. Luckinbill, J.L. Graves, S. Koetsawang and O. Sowirka, Department of Biological Sciences, Wayne State University, Detroit Michigan, USA 48202.

Of all the methods used in the study of the factors controlling senescence, the evolutionary approach has yielded exceptionally promising findings. The application of selective breeding techniques to populations of *Drosophila melanogaster* has produced strains that are improved by as much as 60% in life span.

Comparative studies of these selected strains show improved longevity is accompanied by changes in several pleiotropically related life history features. Flight ability, in particular, is improved by up to 300% in long-lived stocks. Both duration and rate of flight increase. Genetic studies show life span is controlled polygenically by elements on all chromosomes, but predominant control is by probably a single major element located on the third chromosome. These findings suggest several likely genetic and physiological mechanisms by which longevity may be controlled here.

TRANSCRIPTIONAL REGULATION OF GENE EXPRESSION DURING INSECT DEVELOPMENT. J.B. Courtwright*, L. Heilmann, P. Trewitt, C. Milne, J. Wigboldus and A.K. Kumaran, Department of Biology, Marquette University, Milwaukee, Wisconsin 53233, U.S.A.

In order to determine mechanisms of developmental regulation of tissue and stage specific genes, a number of tissue specific genes, e.g., protamine, a testes specific gene, an oocyte specific ribosomal protein gene, melittin, and a vitelline gene, have been identified in cDNA libraries prepared from *Anthonomus grandis*, *Apis mellifera*, and *Drosophila melanogaster*. The corresponding genomic sequences are present in single copy, as detected in Southern blots of genomic DNA and confirmed by the isolation of the appropriate DNA from genomic phage libraries. Both cDNA and genomic sequences for these genes have been used to characterize the tissue, sex, and stage specific patterns of gene expression and to determine these patterns in adults of different ages. These results suggest that homologous genes show similar tissue specific patterns of expression. The effect of starvation and of insect hormones on the stage specific expression of larval hemolymph protein genes was also studied in *Galleria mellonella*. In this case, expression of the last instar specific Lhp gene is blocked by juvenile hormone. We conclude that stage and tissue specific expression in these model systems can be distinguished from aging associated events.

THE INFLUENCE OF DNA REPAIR SYSTEMS ON THE LIFESPAN OF ADULT *DROSOPHILA MELANOGASTER*. I.P. Whitehead, and T.A. Grigliatti*, Department of Zoology, University of British Columbia, Vancouver, British Columbia, Canada V6T 2A9.

The somatic mutation theory of ageing posits that the accumulation of mutations in somatic cells is a fundamental cause of ageing. This hypothesis predicts that longevity may be linked to both the efficiency and integrity of DNA repair systems. It has been demonstrated biochemically that mutagen sensitive (mus) mutations in *Drosophila* are defective in DNA repair. The lifespans of six mus strains, four of which are temperature sensitive (ts), have been measured to determine whether lack of DNA repair substantially influences longevity in *Drosophila*.

When kept at the restrictive temperature, in the absence of any exogenous mutagen, three of the ts mus strains had significantly reduced lifespan, relative to wild-type. When maintained at the permissive temperature, the lifespan of these mus strains did not differ from that of the wild-type strains. In all three cases, the reduction of lifespan was enhanced by sublethal doses of a mutagen, and this effect was also temperature sensitive. These findings suggest that functional repair systems are necessary for normal longevity and imply that spontaneous somatic mutations may influence longevity.

AGE DEPENDENT CHANGES IN THE EXPRESSION OF *DROSOPHILA* PROTEINS. J.E. Fleming, Ryoichi Sasakawa Center for Aging Research, Linus Pauling Institute, 440 Page Mill Road, Palo Alto, California 94306.

We have examined the pattern of gene expression in *Drosophila melanogaster* by two-dimensional protein electrophoresis. Initially, protein gel patterns were analyzed for each of three age groups of (^{35}S)-methionine-labeled adult males. Quantitative analyses of 100 polypeptides were carried out by computer-assisted microdensitometry of fluorograms of the gel preparations. These analyses revealed a significant age-related heterogeneity in the quantitative distribution of radiolabel in these proteins. We have also measured the quantitative expression of heat shock proteins in young and old *Drosophila*. In 10-day-old flies, a 20 minute heat shock results in the expression of 14 new proteins, whereas the identical treatment of 45-day-old flies leads to the expression of at least 50 new proteins. Microdensitometry of the low molecular weight heat shock polypeptides on autoradiograms of 5 age groups revealed that their maximum expression occurs at 47 days for a population of flies with a mean life span of 33.7 days. Collectively, these data are discussed in terms of a "regulatory catastrophe" theory of aging.

HOMAGE TO CARL BÖRNER, OR FIFTY YEARS' PROGRESS IN PHYLOGENETICALLY ORIENTATED LEPIDOPTERA MORPHOLOGY. N.P. Kristensen, Zoological Museum, University of Copenhagen, DK-2100 Copenhagen Ø, Denmark.

Börner's "Die Grundlagen meines Lepidopterensystems", presented at the 1938 Congress of Entomology, admirably utilized the bulk of then available data on Lepidoptera structure to construct a classification (of a kind we would today characterize as 'evolutionary') of the order. Subsequent progress has come at a moderate rate, but at least a basic material of comparative data is now available for all tagmata and major organ systems (perhaps with the exception of the respiratory system) of adult Lepidoptera, while comparative studies on larvae have largely been confined to external features. Application of strict phylogenetic-systematic (cladistic) principles in assessments of lepidopteran structure began with Hennig's "Kritische Bemerkungen zum phylogenetischen System der Insekten" in 1953. An outline of present knowledge of comparative lepidopteran morphology and its bearing on phylogenetic understanding will be presented, and some particularly promising subjects for future research will be discussed.

COMPARATIVE SPERMATOLOGY AS A PHYLOGENETIC INDEX IN LEPIDOPTERA. M. Friedländer, Department of Biology, Ben Gurion University of the Negev, Beer Sheva, Israel.

Lepidoptera spermatogenesis is dichotomous producing concomitant eupyrene (nucleate) and apyrene (anucleate) spermatozoa. No function has been convincingly demonstrated for apyrene spermatozoa although they comprise 50%-90% of the spermatozoa in the inseminated female. Only eupyrene spermatozoa fertilize the eggs while the apyrene ones remain within the spermatheca. Electronmicroscopic analyses show that nucleate/anucleate spermatogenesis is an autopomorphy of Lepidoptera that occurs throughout the order, including the primitive Zeugloptera. It is absent from the closely related sister order of Trichoptera and, apparently, from other Mecopteroidea groups as well. Highly elaborate appendages cover the surface of the eupyrene spermatozoa of the higher Lepidoptera but are absent from those of Zeugloptera and Hepialidae; there is no information concerning this subject on other "lower" systematic groups of Lepidoptera. Comparative spermatology appears to be an useful tool to clarify phylogenetic problems in Lepidoptera and, in particular, those concerning the relations among the lower or primitive systematic groups.

EVOLUTIONARY TRENDS IN LEPIDOPTERAN EMBRYONIC DEVELOPMENT. Y. Kobayashi* and H. Ando, Dept. Biol. Saitama Med. Sch., Moroyama, Saitama 350-04, and Sugadaira Montane Res. Cen., Univ. Tsukuba, Sanada, Nagano 386-22, Japan.

Our comparative study on the embryonic development of primitive moths belonging to the suborder Zeugloptera, Dacnonypha, Exoporia, and Monotrysis, has shown that there are considerable differences among these and the higher suborder Ditrysis in many respects: size of germ disk, formative process of germ rudiment and embryonic membranes, fate of embryonic membranes, condition of the 11th abdominal segment, presence or absence of hydropyle cells, etc.

Many of these embryonic characters also showed the evolutionary trends changing from the primitive or general condition to the advanced or specialized one according to suborders; hence the embryological data can be expected to afford significant means for assessing the phylogenetic relationships among the lepidopteran suborders.

The present paper will represent some examples of the evolutionary trends, and discuss the phylogenetic relationships among the lepidopteran suborders according to the embryological view.

STRUCTURE AND EVOLUTION OF THE NERVOUS SYSTEM IN THE LEPIDOPTERA. J. L. Eaton, Department of Entomology, Virginia Polytechnic Institute and State University, Blacksburg, Virginia 24061 U.S.A.

The structure and evolution of the nervous system of Lepidoptera is examined by comparison to other insects, by comparison within the Lepidoptera, and through changes occurring during metamorphosis.

STRUCTURE AND EVOLUTION OF LEPIDOPTERAN SENSILLA. E. Hallberg, Department of Zoology, University of Lund, Lund, Sweden.

The structure and physiology of the antennal sensilla of moths are well-studied, especially the pheromone-sensitive ones of the males. The antennae of moths usually bear 8-10 different sensillar types, which have a relatively constant appearance among the studied species. Besides different types of olfactory sensilla, there are also sensilla of the taste/tactile and temperature/humidity types on the antennae. The distribution of the sensillar types varies in the different species; there is also a sexual dimorphism depending on the pheromone receptors. In moths certain sensillar types appear to be more variable than other, this is the case with olfactory sensilla along the lateral borders of the antennal surface. Other types, as the thermo/hygroreceptors are present in low numbers, and have a more constant location. Functional adaptations may involve the structure and distribution of the sensilla, as can be seen in *Agrotis*. In addition to external characteristics the properties of the membranes of the sensory cells may change, being tuned to the actual range of odour molecules. The sensillar types and their arrangement is less well-known among the butterflies. In this group there are evidently fewer sensillar types than in moths, as well as lower total numbers of sensilla.

STRUCTURE AND EVOLUTION OF TYMPANIC ORGANS IN LEPIDOPTERA. J. Minet, Muséum national d'Histoire naturelle, Entomologie, 45 rue Buffon, 75005 Paris, France.

Tympanic organs may be defined as paired auditory structures including a tympanum, that is a thin "membrane" connected with sensory components (usually associated to form a scoloparium). Thus defined, the tympanic organs are only known in a few groups of Lepidoptera: many Thyrididae and Nymphalidae, the Pyraloidea, Drepanidae (including Cyclidiinae and Thyatirinae), Geometridae, Hedyllidae, Uraniidae (including Epipleminae and Microniinae), most Noctuoidea and, questionably, the Axiidae and one Tineoid genus. With the exception of this last taxon, all these groups belong to the most advanced Ditrysis (the Obtectomera) and, contrary to a widely-held opinion, there are no tympanic organs - even rudimentary - in the Pseudocossinae (Cossidae). Within the Obtectomera, the tympanic structures are either alar (Thyrididae; Hedyllidae; Nymphalidae), metathoracic (Noctuoidea) or abdominal (Pyraloidea; Drepanidae; Geometridae; Uraniidae, with pronounced sexual dimorphism; Axiidae, with unclear function). More precisely, they represent nine or ten different morphological types, each being characteristic of one important taxon. Whether these various types share true homologies remains however an unsolved question.

STRUCTURE AND EVOLUTION OF MOTH PHEROMONE GLANDS AND GLAND SECRETIONS. Christer Löfstedt, Department of Ecology, Lund University, Helgonav. 5, S-223 62 Lund, Sweden.

The pheromone producing gland of female moths consists of modified intersegmental epidermis and is situated between the 8th and 9th abdominal segments. Male pheromone producing structures are more diverse including abdominal hairpencils, wingglands and glands on the head and the thorax.

Female produced pheromones are structurally similar aliphatic fatty acid derived compounds, usually with 10 to 18 carbon atoms in the skeleton, with one or two double bonds, and with acetate, alcohol or aldehyde functionality. They are produced *de novo* by a small set of enzymes including desaturases, chain shortening enzymes, reductases and acetylases. Male pheromones are chemically more diverse, seemingly diet derived in many species and similar to plant compounds.

The evolution of pheromones and pheromone producing structures in moths is discussed in relation to the phylogeny of major Lepidopteran families.

INSTAR-SPECIFIC ADAPTATIONS OF CIRCULATION AND RESPIRATION IN LEPIDOPTERA

L. T. Wasserthal, Zoological Inst. 1, Staudtstr.5, 8520 Erlangen, FRG.

The caterpillars, pupae and adults in Lepidoptera show very different morphological and physiological adaptations of their circulatory and tracheal systems to different needs of age-specific activities. Important age-specific basic differences concern body weight and fluid content, the need of water retention and the need of using hemolymph as a hydraulic fluid for morphogenesis or for tracheal ventilation.

After wing inflation and extension of the tracheal system a drastic change from a uniform hemocoel into a double-compartment system occurs. After the end of postecdysial diuresis, much of the hemocoel is replaced by the "aerocoel". The positive hemocoelic pressure becomes slightly negative and sets the walls of the air sacs under elastic tension. The influence of the activity of heart and accessory pulsatile organs during eclosion and wing expansion is analyzed by ligature experiments. The relationship between hemolymph content of the wings and the duration of the backward pulse periods of the heart are demonstrated by comparing Saturniid moths with Sphingids and butterflies. Different patterns of abdominal ventilatory movements are found on the generic and family level.

STRUCTURE AND INTERRELATIONSHIPS OF THE NON-DITRYSIAN GLOSSATA (LEPIDOPTERA). E.S. Nielsen, Division of Entomology, CSIRO, GPO Box 1700, Canberra, ACT 2601, Australia.

Our knowledge of the identity, morphology, taxonomy and distribution of the 20 currently recognised non-ditrysiac glossatan families has improved markedly over the last two decades as have aspects of our understanding of their phylogeny. While current morphological evidence demonstrates that most of these families are indeed monophyletic, it also discloses a complex distribution of many characters. The monophyletic nature of several families and the subdivision of the large paraphyletic family Hepialidae into informal monophyletic entities for the purpose of taxonomic/morphological work and phylogenetic reconstruction are discussed. One of the best supported phylogenies is outlined and its consequences discussed. This phylogeny implies that (1) the proboscis muscles are primarily absent in Eriocraniidae and Acanthopteroctetidae and secondarily lost in Lophocoronidae, (2) that Exoporia is the sister-group of the Heteroneura, and (3) the Nepticuloidea are subordinate in Heteroneura. While the immatures of several of the homoneurous glossatans remain unknown, more detailed knowledge is available for the heteroneuran monitrysiac; however, such pertinent questions as the possible monophyly of the 'Monitrysiac' and the sister-group of the Ditrysiac remain unconvincingly answered.

THE MAJOR DITRYSIAN LINEAGES AND THEIR INTERRELATIONSHIPS (LEPIDOPTERA). J. Minet, Muséum national d'Histoire naturelle, Entomologie, 45 rue Buffon, 75005 Paris, France.

Most authors split the ditrysiac Lepidoptera into about fifteen superfamilies. However, according to the cladistic methodology, it is necessary to recognize only monophyletic taxa and, thus, the Ditrysiac have to be divided into more than twenty-five superfamilies. The Tineoidea are the most "primitive" Ditrysiac, but they may constitute a paraphyletic group as their definition does not include any known derived character; the remaining Ditrysiac form a possible clade, based on two regressive traits of the imaginal mouth parts. Within this clade, there is apparently a sister-group relationship between the [Yponomeutoidea+Gelechioidea] and the Apoditrysiac, a large group only distinguished by a slight modification of the abdominal sternum 2. The monophyly of the [Yponomeutoidea + Gelechioidea] may be evidenced by the loss of mobility of the pupal first abdominal segments. This apomorphy is also found in the most advanced Apoditrysiac, thus probably forming a monophyletic taxon: the Obtectomera. The non-obtectomeran Apoditrysiac are most likely paraphyletic and the phylogeny of the obtectomeran superfamilies remains poorly known. However, a striking modification of the imaginal aorta clearly constitutes a synapomorphy between three superfamilies of the Obtectomera: the Hedyloidea, Hesperioidea and Papilionoidea.

THE TINEOID COMPLEX: A REVIEW OF THE BIOLOGY, COMPOSITION, AND PHYLOGENY OF THE MOST PRIMITIVE DITRYSIAN MOTHS. D.R. Davis, Department of Entomology, Stop 127, Smithsonian Institution, NMNH, Washington, D.C. 20560, USA.

As late as 1930 a kind of potpourri of families were recognized under the group name Tineina. Into this "landfill" had been dumped all the ditrysiac Microlepidoptera except Tortricina. Since then most of the obviously non-tineoid families have been referred to other superfamilies. Within the last few years, however, a few, poorly known families (e.g., Douglasiidae and Roeslerstammidae) have been dropped back into the Tineoidea, mostly on the basis of plesiomorphic characters. In the classification proposed, the Tineoidea is restricted to those ditrysiac families typically possessing three or more pairs of apophyses in the ovipositor. Included are Eriocottidae, Tineidae, Psychidae, Pseudarbellidae, Arrhenophanidae, and a new family, Harmaclonidae. Tentatively relegated to the superfamily Gracillarioidea are four families with similar larval biologies. These include Douglasiidae, Roeslerstammidae (=Amphitheridae), Bucculatricidae, and Gracillariidae. The biology and characteristics of each family will be briefly reviewed.

STRUCTURE AND INTERRELATIONSHIPS OF THE TORTRICOID MOTHS (LEPIDOPTERA: TORTRICIDAE). M. Horak, ANIC, Div. of Entomology, CSIRO, G.P.O.B.1700, ACT 2601, Canberra, Australia.

As tortricids contain numerous economically important species they are one of the best documented groups of so-called Microlepidoptera, also with regard to biological information and pheromone data. Combined with recent studies on male genitalia musculature and a hypothetical groundplan for the family this allows a partial reconstruction of tortricid phylogeny.

Two schools of thought are prevailing as far as the higher classification of the family is concerned: 1) two far from congruent systems strongly based on similarities in the male genitalia musculature (Kuznetsov & Stekolnikov/Razowski) and 2) a cladistic approach, supported by pheromone evidence. The resulting classifications are widely different, mainly due to groupings based on symplesiomorphies in the first approach.

Tortricidae doubtlessly are a monophyletic group, but we have so far failed to find a convincing autapomorphy or to identify the sister group. Two of the subfamilies, the Olethreutinae and Chlidanotinae, are demonstrably monophyletic, while the Tortricinae are assumed to be polyphyletic. The majority of the presently recognized tribes appear to be monophyletic, and pheromone data have provided supporting evidence for some disputed taxonomic assignments.

STRUCTURE AND INTERRELATIONSHIPS OF THE PYRALOID MOTHS. Eugene Munroe, Lyman Entomological Museum, McGill University, St. Anne de Bellevue, P.Q. Canada and Bishop Museum, Honolulu, Hawaii, USA.

The Pyraloidea are defined by autapomorphic presence of paired ventral, basal abdominal tympanic organs of a particular type. This definition excludes Thyrididae, Hyblaeidae, Pterophoridae, Tineoidea, Oxychiroidea and Alucitidae. Pyraloidea comprise two families: Dudgeoneidae, with preserved median stem in fore and hind wings, with R₃ and R₄ separate in forewings and with apomorphic reduction of haustellum, maxillary palpi and ocelli; and Pyralidae, with median stem apomorphically lost in fore and hind wings, with maxillary palpi, haustellum and ocelli preserved in most genera. Dudgeoneidae have one genus, with a few species in tropical Africa, Asia and Melanesia. Pyralidae comprise two sister groups, Pyraliformes and Crambiformes, each with several subfamilies and a complex proliferation of genera and species, distributed throughout the world except in Antarctica. Dudgeoneid plesiomorphies indicate an origin among lower Ditrysiac, but apomorphic wing-pattern elements of Pyralidae appear homologous with those of some Gelechioidea and several macrolepidopteran superfamilies, suggesting a direct phyletic relationship.

STRUCTURE AND INTERRELATIONSHIPS OF THE NOCTUOID MOTHS.
J.E. Rawlins, Section of Invertebrate Zoology, Carnegie
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Pennsylvania, United States of America 15213.

Comparative morphological study, especially of larvae
and pupae, from major lineages of Noctuoidea (Noctuidae,
Arctiidae, Lymantriidae, Thyretidae, Aganaiidae,
Notodontidae) has increased knowledge of the taxonomic
distribution of previously recognized characters (larval
chaetotaxy), as well as discovering others of evolutionary
significance (pupal and genitalic). Phylogenetic analysis
reveals monophyletic groups inconsistent with existing
classifications.

A phylogenetic classification for noctuoid families
and major subfamilies is proposed and used to clarify
convergent evolution of distinctive adaptations (larval
locomotion, life history strategies).

STRUCTURE AND BASIC INTERRELATIONSHIPS OF THE
BUTTERFLIES. R. de Jong (Netherlands)

No Abstract

ON THE ORIGIN OF FRAME OF THE PSEUDOTRACHEA IN THE DIPTERA. V.F.Zaitzev, Zoological Institute Academy of Sciences, Leningrad, USSR, 199034.

One of the important moments in the evolution of the labial palpi was the basic rearrangement of their inner surface that began with its flattening and a gradual formation of folds. Thickenings arose in the thickness of the folds of the cuticle on the inner side of the pralabella. In the places of thickenings (compressing) sclerotization process intensified. Thus probably arcs, the elementary links of the bearing structure of the pseudotrachea were formed. Arcs of the frame of the pseudotrachea that arose as a result of thickening of the cuticle and therefore were initially organically fused with it (in the lower Brachycera) were then being transformed in a system of still more autonomous skeletal formations covered with a thin membrane (in the higher Diptera).

INTERNAL ORGANS OF MAYFLIES (EPHEMEROPTERA): A CONTRIBUTION TO ANAGENESIS OF SOME ANATOMICAL STRUCTURES IN INSECTS.

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Some internal organs, namely ventral nerve cord, thoracic and abdominal tracheization, alimentary canal, malpighian tubules, and gonads have been studied in more than 120 recent genera of the order. Apparent anagenetic tendencies are recognizable mainly in the arrangement of malpighian tubules and nerve cord, i.g. gradual fusion of basal parts of ducts of tubules or tendency to further aggregation of ganglia of central nerve system respectively. Anagenetic transitions of the arrangement of remaining organs studied are not so pronounced despite several apomorphic character (e.g. ventral tracheal anastomoses, crop in carnivorous species, multiplied number of gonadal follicles, and others). The arrangement of internal organs of Ephemeroptera can be easily derived from hypothetical arrangement of these organs in insect ancestors. Some character (e.g. nearly autonomous tracheization of some body parts, nearly segmental arrangement of gonads without accessoric organ, very simple digestive tract and others) closely resemble the situation in Apterygota. On the other hand, there are common apomorphies with polyneopterous insects orders as well.

MORPHOLOGY AND EVOLUTION OF THE HEXAPOD HEAD

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The mandibulate cephalon is 6-segmented, the 1st 2 preoral: I clypeolabral (protocerebral), II 1st antennal (deutocerebral, antennular), III cheliceral (tritocerebral, 2nd antennal, supralingual, premandibular), IV mandibular (pedipalpal), V 1st maxillary (gnathochilarial, maxillary), VI 2nd maxillary (labial), the last 2 in a maxillolabial diplosomite appended to cranium I-V w/ganglia IV-VI coalesced to form the subesophageal ganglion, III (1st postoral) having shifted frontolaterally to join I-II. The mandibular postergite (vertex+genae) is the occiput, and maxillolabial diplosomite the postocciput of most authors. The clypeolabrum is a fused coxopodite pair, endites forming epipharyngeal lobes and (fused) labrum; in Monura and Thysanura+Pterygota, labrum is a 2nd division. Appendages II have shifted out of oral cavity in recent arthropods, and III also in postlarval Crustacea after serving as gnathopods prior to development of mandibles. Antenna 1 is primitively 8-segmented as still in Diplopoda and some Crustacea, but all save the basal 2 podites tend to become annulated. The superlinguae have intrinsic endite muscles, may combine w/sternum IV (lingua, paragnaths) to form a hypopharynx. Mandibles are ankylized coxopodites+endites in Crustacea (w/telopodite+palp), Hexapoda (palp lost) but uncombined in Myriapoda (palp lost). There are 5 types of anterior articulations in Hexapoda from mere opposing faces to tongue-and-groove sliders, and loose and permanent pivots. Maxillae 1,2 were fully segmented leglets in most Paleozoic insects; 2 is basally fused w/each other+sternum VI w/2nd transverse hinge(s) to form the true labium in Hexapoda. The analog in Diplopoda, Paupoda is derived from maxilla 1+sternum V, associated w/superlinguae, lingua: maxilla 2 is wanting, 1st trunk legs vestigial.

ONTOGENY OF PHALLUS OR PENIS IN CERTAIN MALE INSECTS. Ujjal Singh Bhatti, Zoology Department University of Delhi, Delhi, India. 110007.

Origin and homology of the greatly diversified architecture of male copulatory equipment in insects is not fully known. Investigations on the ontogeny of phallus or penis in male insects belonging to different Orders i.e., *Achoea janata* L. (Lep.), *Polistes olivaceus* (Hym.), *Aedes aegypti* L. (Diptera), *Dysdercus koenigi* Fab (Hemiptera), *Schistocerca gregaria* Forskal (Orth) etc., were initiated to seek evidences of its origin and differentiated with a view to point that 'Ontogeny recapitulates phylogeny'. Through differentiation, few hypodermal precursor cells were observed to produce discoidal primordia or genital discs. The latter remained attached to the parent genital sternum of 9th abdominal segment throughout the larval period. At the apex of this imaginal primordia developed the primary phallic lobes which eventually differentiate into the inner mesomeres and outer parameres. The former by an elaborate mechanism develop into the phallus proper. While the outer ones form the claspensor parameres.

STUDIES ON THE MALE REPRODUCTIVE ORGANS IN THE FAMILY CURCULIONIDAE (COLEOPTERA). Amar Shobha* and H.R. Pajni, Department of Zoology, Panjab University, Chandigarh, India.

A study of the internal male reproductive organs in 108 species under 49 genera and 24 subfamilies of family Curculionidae reveals that the male reproductive system is built up on the general coleopteran plan. It consists of 1-2 pairs of testis, paired seminal vesicles and paired accessory glands. A majority of the subfamilies have 2 pairs of testes, but a few of them have a single pair. The testis is usually multifollicular, sometimes bifollicular and occasionally monofollicular. The seminal vesicle is globular, with or without forming distinct lobes. There is present 1 pair of bilobed accessory glands with unequal arms opening into the vas deferens close to the seminal vesicle. The number of accessory glands varies from 1-6 pairs in the subfamily Brachyderinae and 3 pairs in subfamily Apoderinae. The structure and function of the seminal vesicle reveal that its lobes sometimes enlarge in the form of accessory glands, showing the absence of seminal vesicle. The ejaculatory duct is a narrow and tapering tube in most of the species. However, it is surrounded by a cluster of specialised glands of uncertain function in the genus *Matialma* of subfamily Zygopinae. Significance of the variations at the level of species and genera has been discussed.

LENS DIVERSITY IN THE SUPERPOSITION COMPOUND EYES OF TROGID BEETLES. S. Caveney* and C.H. Scholtz†, Department of Zoology, University of Western Ontario, Canada N6A 5B7, and †Department of Entomology, University of Pretoria, South Africa 0002.

The ommatidium in the compound eyes of many *Omorogus* spp (Trogidae, Scarabaeoidea) has a unique arrangement of three distinct lenses - a corneal facet, an attached corneal exocone and an underlying crystalline cone (Can. J. Zool. 64: 1787, 1986). The relative sizes of the exocone and crystalline cone vary considerably in the group. We investigated whether this was due to ancestry or to the functional demands placed on the eye in species of differing behaviour and habitat. Lens dimensions were measured for 55 *Omorogus* spp. from three continental regions (Africa/India, Australia and the Americas) and three biomes (temperate, subtropical and desert) and for 9 *Trox* spp. While the ancestral *Trox* eye was eucone, that of *Omorogus* was duocone (all three lenses). The latter is present in all actively-flying nocturnal species widely distributed in all three regions. Duocone ommatidia reverting back to the eucone condition are found in species of limited flight and distribution, and this ommatidium in similarly reduced in unrelated and flightless desert species on two continents. Possible extrinsic and intrinsic factors affecting eye structure in *Omorogus* are discussed. Supported by NSERC of Canada.

COMPARATIVE MORPHOLOGY OF THE MOUTHPARTS AND HIND LEGS OF THE COLLETIDAE (APOIDEA: HYMENOPTERA). J.D. Plant, Universität Freiburg, Institut für Biologie I (Zoologie), 7800 Freiburg, FRG.

The Colletidae are commonly regarded as the most primitive bee family. Results of this study show that there is considerable variation in the morphology of the mouthparts, more than in any other bee family. A proposed cladogram for the subfamilies of the Colletidae is discussed.

The hypothesis of Malyshev (1968), that bees originated from digger wasps (Pemphredoninae: Sphecoidea) was tested by a morphological comparison of these wasps to the Hylaeinae.

The following assertions were supported: the Euryglossinae are the most primitive of the Colletidae; the bifid glossa is ancestral to the derived acute glossa; the mouthpart similarity between the Xeromelissinae and the Halictidae is convergent.

Relationships between the Colletidae and the other major groups of short-tongued bees is discussed.

COMPARATIVE PHYLOGENETIC STUDIES ON THE SILK-THREAD FORMATION AND THE TUBE-BUILDING OF THE LARVAE OF GLYPTOTENDIPES PALLENS AND TELMATOGETON JAPONICUS (DIPTERA: CHIRONOMIDAE). P. TONJES, University of Bremen, Department of Biology, NW II, Leobenerstr., 2800 Bremen 33, FRG.

Our investigations on the morphology, ultrastructure and histochemistry of the larval salivary gland (s.g.) and the s.g.-secretion of *Glyptotendipes pallens* (Subfamily Chironominae) as well as *Telmatogeton japonicus* (Subfamily Telmatogetoninae) have revealed great differences, which will be presented in this contribution. The s.g. of the larvae of *T. japonicus* (long, tube-like and asymmetrically) produce a great quantity of two types of secretion, which aggregate and form one structured thread-like secretion in the s.g.-reservoir. In comparison with *T. japonicus*, the short, flat-like s.g. of *G. pallens* produce an amorphous secretion, which apparently is transformed to the final silk threads during the process of extrusion. The behavior of *T. japonicus* differs from all other chironomids: The larva produces a strong thread, by which it attaches itself to the substratum, in order to prevent being flushed out in the marine intertidal zone. The presented results will be discussed in respect of chironomid phylogeny.

A REINTERPRETATION OF THE HYPOPIGIUM OF MICROPHOR HOLOSERICUS (MEIGEN) (DIPTERA, EMPIDOIDEA). H. Ulrich, Zoologisches Forschungsinstitut und Museum Alexander Koenig, Adenauerallee 150-164, 5300 Bonn 1, W. Germany.

A reexamination of the male genitalia, including musculature, of *Microphor holosericeus* led to results which disagree with the figures and interpretations of the same species as given by Hennig, 1976: 1. The so-called telomeres of *M. holosericeus* are not homologous with the muscled appendages known under the same term in Dolichopodidae; likewise, their homology with the gonostyli, or telomeres, of the brachycerous groundplan is improbable. They are glandular organs with deeply invaginated bases and seem to constitute an autapomorphy not shared even by other *Microphor* species. 2. The hypandrial, or dorsal, bridge is reduced. Apparently Hennig confused it with the endophallic sperm pump. In both characters, he overlooked membranes and mistook the underlying internal structures for parts of the outer surface. These errors by an experienced worker should serve as an example that skeletal structures may be more complicated than expected from their superficial appearance, and that there is need for detailed studies with improved techniques.

VARIATIONS ECOLOGIQUES DU DISQUE POSTERIEUR DES LARVES DE SCIOMYZIDES. J.C. Vala*, C. Gasc et S. Manguin. Faculté des Sciences, 33, rue Louis Pasteur, 84000 Avignon (France).

D'après la forme des lobes périphériques du disque postérieur et le développement des soies hydrofuges des plaques spiraculaires, les larves se classent en 4 groupes écologiques. a) Larves aquatiques typiques : lobes longs associés à des soies moyennement développées. Exemple : *Sepedon sphegea*, *S. spinipes*, *Tetanocera ferruginea*, *Ilione albiseta*. b) Larves aquatiques intermédiaires : lobes et soies moyennement développées. Exemples : *Hydromya dorsalis*, *T. arrogans*. c) Larves terrestres typiques : lobes petits et arrondis, soies vestigiales en ecaille. Exemple : *Euthycera cribrata*, *E. stichospila*, *Dichetophora oblitterata*, *Coremacera marginata*, *C. catenata*, *Salicella fasciata*. d) Larves terrestres intermédiaires : lobes petits et arrondis, soies moyennement développées. Exemple : *Trypetoptera punctulata*.

CLUSTER FORMATION IN A PANOISTIC OVARY. M. Pritsch, J. Büning*, Institute of Zoology I, University of Erlangen, D-8520 Erlangen, F.R.G.

Parthenothrips dracenae has a panoistic ovary as known from the whole order of Thysanoptera. Here, as in all panoistic ovaries, the oocyte genome itself has to govern the euplasmatic growth without help of sister cells, determined as nurse cells. The Thysanoptera are the only known group among the Paraneoptera without nurse cells (The ovariole structure of Zoraptera is uncertain). The question is to ask whether this panoistic ovary is primarily panoistic or is it deviated from a formerly meroistic status. Ultrathin serial sectioning clarified the situation: In the germarial region one isolated cell was found on top, interpreted as stem cell or cystoblast, followed by a cluster of 4 cells, derived from a 2-cell status by synchronized divisions. The oldest and largest cell cluster comprises 8 cells. Its topography of intercellular bridges gives strong evidence for a 16-cell cluster in which 8 cells have detached already. Polyfusomes are found. Nurse cells do not exist. All detached cells develop as oocytes. Thus Thysanopterans are secondary panoists with normal meroistic cluster development (2ⁿ-rule), but all cystocytes will be determined as oocytes.

THE ACROBLAST IN THE FIREBUG *PYRRHOCORIS APIERUS* L. (HETEROPTERA): MIGRATION, FORMATION OF ACROSOMAL VESICLE AND EVIDENCE FOR MEMBRANE DIFFERENTIATION. J. Godula, Department of Zoology, Jagiellonian University, Krakow, Poland.

Migration of acroblast around spermatid nucleus is a characteristic phenomenon during spermatogenesis in *P. apterus*. The migrating acroblast moves from the distal to the proximal pole of the nucleus and then back to its basal region. During this migration, the acroblast forms acrosomal vesicle which enlarges gradually and comes into close contact with a modified nuclear envelope. The modification of the nuclear envelope (fusion of its two membranes into a single lamella) is synchronized with the movement of the acroblast-acrosomal vesicle complex. Following migration, the acroblast separates from the acrosomal vesicle and translocates to the caudal part of the spermatid, while the acrosomal vesicle transforms into the acrosome. It has been demonstrated that the formation of acrosomal vesicle is related to the process of membrane differentiation in the acroblast. Hypotheses explaining the possible mechanism of the whole acroblast-acrosomal vesicle complex migration are discussed.

ORIENTATION OF MITOTIC SPINDLES: THE ROLE OF POLYFUSOMES IN CYSTOCYTE CLONES OF *DROSOPHILA MELANOGASTER*. P.D. Storto* and R.C. King, Dept. of Evolution, Northwestern University, Evanston, IL, USA.

Higher insects have evolved a method for loading their eggs with nutrients which involves nurse cells that produce the compounds and a system of canals through which the products are exported to the oocyte. Such oocyte/nurse cell syncytia are formed in insects with polytrophic merostic ovaries, such as the Hymenoptera and Diptera. These have egg chambers in which each oocyte is one member of a clone of interconnected cells. In *Drosophila* each syncytium contains 16 cells, and is derived from one oogonial cell which undergoes four cycles of mitosis with incomplete cytokinesis. Sibling cells remain connected to one another via ring-shaped canals. A gel-like structure, termed a fusome, resides within each canal during mitosis, and adjacent fusomes fuse to form a polyfusome extending throughout the clone. The clone forms a branching chain of cells with a specific pattern of interconnections. We have reconstructed the 3-D structure of polyfusomes in clones undergoing the final division, and found that each spindle had one pole joined to the polyfusome. We hypothesize that the polyfusome may serve in orienting dividing cells, and in determining the precise pattern of interconnections. This may provide a cue for the clone to stop dividing, and be an oocyte-determining factor.

ISOLATION OF AN ABD-A-LIKE HOMEO BOX FROM THE *MANDUCA SEXIA* GENOME. L.M. Nagy*, R. Booker, L.M. Riddiford, Department of Zoology, University of Washington, Seattle, Washington.

A great deal is known concerning the process of segmentation in *Drosophila melanogaster*, especially concerning the activity of specific "segmentation" genes. Other insect species segment with overtly different morphological patterns than *Drosophila*. The experiments undertaken here intend to relate morphological differences in the segmentation of different species of insects to alterations in the structure, organization and expression of developmentally important genes. We report here the molecular cloning and nucleotide sequencing of a homeo box region from the *Manduca* genome. Nucleotide sequencing reveals a region which encodes a 67 amino acid stretch within the *Manduca* genomic clone with 100% similarity to the homeo box containing exon of the *Drosophila* ABD-A gene. A 4.7 kb poly A+ messenger RNA, which hybridizes to a probe from the *Manduca* homeo box region, is found in post-gastrulation embryos, as well as 5th instar nervous system and muscle tissue.

TIBIA TO FEMUR RATIOS OF REGENERATED LEGS IN STUMPY GERMAN COCKROACH. A. Tanaka*¹ and M.H. Ross², ¹Department of Biology, Nara Women's University, Nara 630, Japan, and ²Department of Entomology, Virginia Polytechnic Institute and State University, Blacksburg, Virginia 24061, USA.

In wild-type legs, the ratio of tibia length to femur length is low in the foreleg, high in the hindleg, and intermediate in the midleg throughout larval instars up to the adult stage. After autotomy at the trochanterofemoral articulation, regenerates from foreleg coxae show intermediate tibia/femur ratios between the normal foreleg and midleg, and those from the hindlegs, intermediate between the normal hindleg and midleg. Those from the midlegs are unaltered in the ratios. Similar studies were made on a mutant, stumpy (*sty*), which has shorter legs than wild-type. The tibia/femur ratios of *sty* fore-, mid-, and hindleg were, respectively, similar to those of regenerated wild-type. This suggests that *sty* may have primitive legs insufficiently differentiated from midleg-like nonspecific forms. The tibia/femur ratios of regenerated *sty* legs were similar to those of the unoperated controls when the legs were autotomized in early instars. When the legs were autotomized in middle and late instars, the ratios of *sty* regenerates increased in all legs. In the adult regenerates, the ratios of fore-, mid-, and hindleg almost reached those of *sty* midleg, *sty* hindleg, and wild-type hindleg, respectively.

DEVELOPMENT OF WING MOTOR SYSTEM DURING METAMORPHOSIS IN THE SILK MOTH, *BOMBYX MORI* (LEPIDOPTERA: BOMBYCIDAE). H. Tsujimura, Laboratory of Biology, Tokyo University of Agriculture and Technology, Fuchu, Tokyo 183, Japan.

During metamorphosis, some larval motor neurons which innervate mesothoracic dorsal longitudinal muscles (DLMs) degenerate but others survive and become adult wing motor neurons, while all larval DLMs degenerate and adult muscles develop *de novo*. In this study we investigated changes in dendritic morphology and ramification of axon terminals of these DLM motor neurons by axonal cobalt filling and silver intensification methods.

In early stages of metamorphosis some larval dendritic and axon terminal branches degenerated and dendritic field and axon terminal field decreased. Moreover, relative position of the dendrite in the ganglion shifted somewhat. In early and middle pupal stage new branches started to grow from remaining dendrites and axon terminals. Many filopodial extensions occurred on the surface of the dendritic branches. In late pupal stage large field of complex dendritic branches and great ramification of axon terminals were completed to compose specific adult pattern of motor neuron morphology.

This result shows that specific adult neural circuits which DLM motor neurons participate in are reorganized during metamorphosis, though somata and axons are reused.

METAMORPHIC CHANGES OF THE ANTENNA AND ITS NEURONS IN THE SILKWORM, *BOMBYX MORI* L. (LEPIDOPTERA). Yoshio Waku* and Yasuhisa Endo, Department of Applied Biology, Kyoto Institute of Technology, Matsugasaki, Kyoto, Japan.

One larval antenna of the silkworm has 11 sensilla with some 50 neurons. Antennal imaginal disc (multilayered epidermal tissue) is located under the larval antenna and communicates with it. Cell proliferation, death, movement, relocation and shape change etc. in the antennal tissue and imaginal disc occur consecutively during larval development and pupative metamorphosis, together with partial degeneration of the larval neurons. Antennal nerve cords consisted of survived larval axons and glial cells, however, persist through pupation period. The pupal antenna just after pupation consists of monolayered tissue of epidermal cells with long cytoplasmic protrusions. Within this epidermal tissue, numerous 'pupal neurons' appear throughout the entire antenna and then elongate their axons to join and recruit the once thinned larval nerve cords. Two days after pupation, thousands of adult neurons begin to appear in the developing adult antennal tissue to construct functional olfactory sensilla and thicken the nerve cords with their axons to establish the olfactory nerve.

CORNEAL LENS FORMATION OF THE COMPOUND EYE IN THE CABBAGE BUTTERFLY, PIERIS RAPAE L. (LEPIDOPTERA). C.W. Kim, C.S. Kim and W.K. Kim, Department of Biology, Korea University, Seoul 132, Korea.

Ultrastructure and formation of the adult corneal lens in cabbage butterfly, Pieris rapae L. was observed using EM. The adult cornea consists of epicuticle, 31 lamellar exocuticle, endocuticle and corneal process. The surface of the corneal lens is studded with protrusions (nipples). Interommatidial hairs are observed randomly at the points where three hexagonal facets meet. When pupal ecdysis was completed, microvilli arise from the corneagen cells, the crystalline cone cells and the pigment cells, and the nipples are formed by the microvilli later. At the below of the nipples, 2 corneagen cells and 6 pigment cells deposit the cuticle, and the corneal process is created by the 2 corneagen cells. Formation of the rest parts of the cornea was also discussed.

ULTRASTRUCTURE AND DEVELOPMENT OF THE LATERAL PALATAL BRUSH IN LARVAL Aedes Aegypti (LINNAEUS) (DIPTERA: CULICIDAE) K.M. Fry, Department of Environmental Biology, University of Guelph, Guelph, Ontario, Canada N1G 2W1

The development of the lateral palatal brush (L.P.B.) in larval Aedes aegypti was observed at the light and electron microscopic levels at three hour intervals from second instar ecdysis to third instar ecdysis. Immediately after second instar ecdysis the epidermis apolyses from the lateral palatal pennicular area (L.P.P.A.). The L.P.B. filaments grow as cytoplasmic extensions into the ecdysial space. After the filament rudiments have reached their final length, cuticulin, inner epicuticle, and procuticle are deposited. The L.P.P.A. and the cuticular crossbars that the L.P.B. filaments insert on, are produced after the filaments have been completed.

Organelles for plasma membrane and cuticle development begin the developmental cycle at the base and middle of the cells. As the filament rudiments grow, most of the rough endoplasmic reticulum, mitochondria, and Golgi complexes are found in the apex of the epidermal cells and in the filament rudiments. After the L.P.B. filaments, L.P.P.A., and crossbars have been formed, extensive organelle autophagy occurs within the epidermal cells.

THE LOCALIZATION OF THE DRIVING OSCILLATOR SYSTEM OF THE CIRCADIAN ENDOCUTICLE GROWTH IN COCKROACHES (BLATTODEA). F. Weber, Zoological Institute of the University, D-44 Münster, FRG.

It has been supposed that a circadian growth of the endocuticle is under the control of a peripheral oscillator system. In cockroaches (Blaberus craniifer) this hypothesis has been confirmed by in vitro cultures. Pieces of the hind tibiae, excised immediately after the imaginal moult, were cultured in Marks' medium M20. Frequently, at the basis of bristles a circadian temperature-compensated growth rhythm (alternating helicoidally and unidirectionally structured layers) was observed, whereas outside the basis of the bristles all material deposited in vitro resembles the non-circadian, helicoidal structure of the exocuticle. From these results it is concluded that the driving oscillator system resides in the hypodermis itself. Possibly, the hypodermis at the basis of the bristles functions as a pacemaker. This peripheral oscillator system seems to be switched on by a central (hormonal) signal during the moulting sequence. Obviously, the process of induction was already terminated, before the leg pieces were taken into culture.

EFFECT OF TWO BENZOYLPHENYL UREAS ON THE ULTRASTRUCTURE OF THE LARVAL INTEGUMENT OF MUSCA DOMESTICA L. (DIPTERA: MUSCIDAE). D. Degheele, M.F. El-Saïdy, G. Hegazy & M. Auda. Laboratory of Zoology, Faculty of Agricultural Sciences, Coupure Links 653, B-9000 Gent, Belgium.

The epicuticle of untreated larvae is composed of a superficial layer - an outer epicuticle, a cuticulin layer and an inner epicuticle. The procuticle layer contains 4 parallel lamellae in the first, 7 in the second and 24-30 lamellae in the third larval instar. A subcuticle is separating the procuticle from the epidermal layer and is consisted of a loosely packed region of protein and chitin fibers without any defined orientation.

The epicuticle formation is not disturbed in the three larval stages after application of diflubenzuron containing artificial diet. However, the formation of chitin fibers in the procuticle is completely blocked and looks as an amorphous material, sometimes containing aggregations of dense granular material. The subcuticle layer is not distinguished in treated larvae. The microvillae of the epidermis are less numerous. The nucleus is irregular shaped and contains less dense chromatin material. Similar effects are obtained after a chlorfluazuron treatment.

LIGHT - AND ELECTRONMICROSCOPIC STUDIES OF THE CORPORA CARDIACA OF HYDROPHILUS OLIVACEUS FABR. (COLEOPTERA: POLYPHAGA). H.S. Gundevia, Harish-chandra Postgraduate College, Varanasi-221001, INDIA

The corpora cardiaca of H. olivaceus is composed of nervous, glandular and glial parts. The nervous part forms the central core of the gland, which is surrounded by the glandular part. The glandular part is made up of electron-dense chromophilic and electron-lucent chromophobic cells distributed randomly with glial elements. The electron-dense cells react positive with PF-technique and they are cysteine-rich in nature. These are unipolar neurons with thin elongated axons which communicate with the central nerve core of corpora cardiaca. They possess electron-dense material which is peptidergic in nature. The chromophobe cells exhibit electron-lucent material in their cytoplasm and are aminergic in nature. The corpora cardiaca function as a neurohaemal organ which not only stores the protocerebral neurosecretory material but also produces its own peptidergic and aminergic materials.

FINE STRUCTURE OF THE SALIVARY GLAND AND ROLE OF HAEMOLYMPH PROTEINS IN SALIVARY SECRETION IN A BUG, *LETHOCERUS INDICUS* LEP. & SERV. (HEMIPTERA:BELOSTOMATIDAE). Dinesh Kumar* and P.R. Yadav, Department of Zoology, Banaras Hindu University, Varanasi - 221 005, India.

Ultrastructure of the principal salivary gland of *L. indicus*, consisting of syncytial epithelium, reveals that the lobule is made up of a thick basement membrane on which rests the basal membrane having several infoldings. The apical membrane encircles a large lumen wherein it is thrown into numerous microvilli. The cytoplasm contains large polyploid nuclei surrounded by a double nuclear membrane. Several mitochondria are observed throughout the cytoplasm. The protein synthesising machinery exists in the form of numerous small rough endoplasmic reticulum vesicles. The collation of electropherograms reveals that the gland sequesters some of the protein fractions from the haemolymph which are ultimately secreted and poured from the fat bodies. ³H-uridine incorporation into the nuclei shows the hectic protein synthetic activity in the gland. The present investigations depict the heterosynthetic origin of the saliva.

ULTRASTRUCTURAL CHANGES OF COCOONASE SECRETION IN THE GALEA OF SILKWORM, *BOMBYX MORI*. H. Akai, Sericultural Experiment Station, Tsukuba, Ibaraki 305, Japan.

Ultrastructural changes of the galea of *Bombyx* silkworm during the pupal development were studied by light and electron microscopic observations. Epidermal cells of galea just before the eclosion contains a large numbers of opaque materials in their cytoplasm, especially in the apical regions. At the beginning, small size of dense globules, about 200 nm in diameter, are produced in several regions concentrated with the rough endoplasmic reticulum in the cytoplasm, and then they conjugate each others and make a large size of dense material finally. These materials move to the apical regions in the cell where locate the secretory pores, and are secreted on the cuticular surfaces. Just after the emergence, however, these materials are completely disappeared in the cells. There are, sometimes, only detected a small numbers of the digested materials. By scanning electron microscopic observations, there are detected numerous pores connecting to the inside and a large amount of accumulated secretory materials on the cuticular surface.

From these observations, it was cleared that these materials are released in only limited time of emergence from the galea to digest the cocoon shell to escape from the cocoon.

MOUTH-PART STRUCTURES IN RELATION TO FOOD HABIT OF *MICRASPIIS DISCOLOR* (F.) (COLEOPTERA:COCCINELLIDAE).

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Micraspis discolor (F.) is an oriental species of Coccinellidae commonly found in India. Both the adults and the larvae feed on aphids and can also subsist on pollen of various crops and herbaceous weeds. We report on the species phenology, food range, feeding capacity and developmental periods under laboratory conditions. Detailed studies were carried out using SEM to reveal the relationships between the mouth-part structures and the species food habit. It was found out that the essential nutritional sources were from predation on aphids such as *Aphis gossypii* G., *A. citricola* v.d.G. and *A. craccivora* K.W. the aphid prey are scarce or absent in nature, the species would feed on pollen of *Brassica campestris* L., *Ageratum conyzoides*, *Eupatorium odoratum*, as substitute food. The larval mouth-parts are efficiently used to collect the alternative food (pollen) with a specialized part of the mandibles. Considering the specialized mouth-part structures adapted both for predation and pollinivory, *M. discolor* might be a possible biological control agent in an environment where the prey aphid population levels are fluctuating.

STRUCTURAL ORGANIZATION OF THE BRAIN AND SUBOESOPHAGEAL GANGLION OF MALE *Aedes Aegypti* (L.) (DIPTERA: CULICIDAE). J.M. Nyhof* and S.B. McIver, Department of Environmental Biology, University of Guelph, Guelph, Ontario, Canada N1G 2W1.

A description of the brain and suboesophageal ganglion of male *Aedes aegypti* (L.) is described from silver-stained semithin (0.5 µm) serial sections of whole heads, an Auto CAD (Version 2.6) computer generated brain reconstruction, dissected brains observed in the scanning electron and light microscopes, and Golgi-Cox and Cobalt Chloride preparations. The brain and the suboesophageal ganglion of *A. aegypti* are fused into a single structure. The brain consists of three paired divisions, the protocerebrum, deutocerebrum, and tritocerebrum located above the oesophagus. Structures within these regions include the protocerebral lobes, the mushroom bodies, central complex of the protocerebrum, and the mechanosensory region and olfactory lobes of the deutocerebrum. The general structure of the tritocerebrum, suboesophageal ganglion and the various tracts and commissures within the brain are discussed.

STRUCTURE AND PHYSIOLOGY OF NEURONS IN THE ANTENNAL LOBES OF THE HONEYBEE, *Apis mellifera*. D.Flanagan* and A.Mercer, Department of Zoology, University of Otago, Dunedin, New Zealand.

The antennal lobes are the primary olfactory centres in the insect brain and represent the first region of interaction between incoming antennal sensory information and central processing systems in the brain. The morphology and response characteristics of neurons in the antennal lobes of the bee brain have been examined using intracellular recording and cobalt staining techniques. On the basis of morphology, 3 categories of local interneuron have been identified. The majority of local interneurons were found to be heterogeneous in appearance having a concentration of arborizations in one or a few glomeruli as well as sending more diffuse projections into other glomeruli within the antennal lobe. Neurons that project beyond the deutocerebral neuropil were examined also and subdivided into 4 categories on the basis of their morphological characteristics. Specific glomeruli invaded by cells recorded in this study were identified, where possible, using an atlas of the antennal lobes constructed using computer reconstruction techniques.

The relationship between the morphology and response characteristics of deutocerebral neurons identified in this study will be discussed.

THE LEPIDOPTERAN STEMMA: ULTRASTRUCTURAL NEUROANATOMY AND CIRCADIAN DYNAMICS OF PHOTORECEPTOR MEMBRANE AND ORGANELLES. S.R. Zetlan and S.D. Carlson*, Department of Entomology, Neurosciences Training Program, University of Wisconsin, Madison, WI 53706, U.S.A.

The Larval European Corn Borer (*Ostrinia nubilalis*) has 12 stemmata eyes; 6 on each side of the head capsule. Each stemma has 7 retinular (R) cells arrayed in 2 tiers. R axons project to ipsilateral protocerebral glomeruli. Ultrastructure (TEM, SEM) of lens, cone, R cells, glia, nerve and neuropil are detailed. We propose breakdown of photoreceptor membrane occurs by pinocytosis at light onset, and that membrane is degraded in lysosomal cascade. Coated vesicles are present at microvillar bases shortly after light onset. Multivesicular, combination and multilamellar bodies increase in size and number within 2 hours after light onset, wane 2 hours later and remain low throughout the remainder of the photoperiod. Secondary lysosomes are sometimes contiguous with SER. Additionally, there is a diurnal fluctuation in size, number and morphology of myeloid bodies (MB) and other forms of SER in R cells. MB number is lowest immediately after light onset and increases throughout the photoperiod. Ultrastructural changes in R cell organelles are placed in a cell biology perspective. We advocate the stemma as a model photoreceptor system.

STRIDULATORY APPARATUS AND SOUND PRODUCTION IN COLEOPTERA PALPICORNIA. Q. Pirisinu°, G. Spinelli°*, M.C. Bicchierai°, G. Guidarelli°° and G. Paparo°°, (°) Institute of Zoology, University of Perugia, Italy; (°°) Institute of Acoustics "O.M. Corbino", C.N.R., Rome, Italy.

The stridulatory organs of Coleoptera Palpicornia belonging to the Italian fauna, were comparatively examined with SEM. Significant differences in the form and extent of the plectrum, located on the inner face of the elytron, were pointed out. Differences were also found in the uropleural pars stridens. The pleural denticulations are often associated with ridges so the structure of the pars stridens can be either denticulated or lamellated.

Sounds emitted under mechanical stimulation were recorded using an electro-acoustic system composed of a hydrophone, a pre-amplifier and a magnetic tape recorder; this system has a good linearity and flat response in the audible range of frequency.

Sonagrams of the sounds emitted by the species examined show a spectrum ranging from 0.5 to 8 kHz, with specific differences in the zones of greater frequency intensity.

MORPHOLOGY, BIOLOGY AND ECOLOGY OF *CATAGAPETUS NIGRANS* McL. (TRICHOPTERA: GLOSSOSOMATIDAE). G.P. Moretti, M.C. Bicchierai*, F. Cianficconi, C. Corallini and G. Spinelli, Institute of Zoology, University of Perugia, Perugia, Italy.

Catagapetus nigrans is a species endemic to the Apennines (Italy). This species is typical of the hills and mountains rheocrenal and it is found in clear cold waters which have not been affected by pollution. The pupae often gather in compact groups on the upper surface of submerged stones.

The larval case is domeshaped, made of sand, and has two chimneys which serve to change the water inside; the pupal case is made out of tiny pebbles tenaciously attached to the stones. The larva feeds mainly on diatoms. The emergence occurs in spring and summer; the male has androconia on the first and second abdominal segments, and their structure was examined with SEM.

We described the morphological and taxonomical characteristics of the larva, pupa, pupal exuvia, imago, and we were able to explain the life-cycle and ecology of the aquatic stages.

LOCOMOTOR ADAPTATIONS OF CARABID BEETLES:

DOES FUNCTIONAL ANATOMY REFLECT PHYLOGENY?

M.E.G. Evans, Department of Environmental Biology, Manchester University, Manchester M13 9PL, U.K.

Within the Carabidae, several functional groups can be distinguished on the basis of locomotor capabilities. For instance, there are three large groups with different running/pushing abilities which correspond (approximately) to differences in leg structure. Could these functional anatomical features be used in phylogenetic classifications? If so, they might help to define (say) carabid subfamilies, since traditional ("non-functional") definitions produce rather similar groups.

The problems are that the correlations between function and structure are not exact, there are overlaps between groups, and convergent evolutionary lines may be grouped together because their functional similarities are superficial. These problems also apply at a tribal level. Most tribes exhibit one particular locomotor design, but the larger tribes may occupy a wide adaptive zone, and show a considerable range of locomotor variation. The answer to the title question seems to be yes and no. However, locomotor characters define lifestyles, and should prove a valuable aid to phylogenetic reconstructions provided we can distinguish between convergent evolutionary lines.

FUNCTIONAL TRENDS IN INSECT WING EVOLUTION. R.J. Wootton, Department of Biological Sciences, University of Exeter, Devon, U.K. EX4 4PS.

A decade of comparative studies on the detailed morphology and mechanics of wings and the kinematics of flight, combined with recent advances in aerodynamic theory, have greatly elucidated the principles of insect wing design. Many familiar characters and evolutionary trends can now be seen to make good functional sense.

ENZYMATIC PROPERTIES OF THE SECRETION OF THE FEMALE REPRODUCTIVE ACCESSORY GLANDS OF *CERATITIS CAPITATA* (DIPTERA, TEPHRITIDAE). R. Dallai*, D. Marchini, L.F. Bernini, G. Del Bene and G. Melis-Porcinai, Department of Evolutionary Biology, University of Siena, Italy.

It is now clear that medfly eggs have a micropylar cap whose structure is an integral part of the chorion (Dallai et al., 1986). The secretion of the female accessory glands does not remove such cap which apparently remains morphologically unchanged in ovary and laid eggs; however it modifies the lectin-binding sites for N-acetyl-galactosamine residues (Dallai et al., 1987). In the secretion the presence of the N-acetyl-β-D-galactosaminidase, the N-acetyl-β-D-glucosaminidase and alkaline phosphatase has been detected. Such enzymes whose activity was measured might produce changes on the chemical structure of the cap somewhat important for fertilization.

Dallai R., Marchini D., Callaini G., Fanciulli P.P., Del Bene G. and Melis-Porcinai G. (1986). REDIA, 69:313-327.

Dallai R., Del Bene G., Fanciulli P.P., Melis-Porcinai G., Callaini G. and Marchini D. (1987). In: Fruit Flies: Proceed.II.Int.Symp., Crete, A.P. Economopoulos ed., Elsevier Science Publishers, pp. 61-70.

MORPHOMETRIC COMPARISON OF MIGRATING AND NON-MIGRATING MORPHS OF *BEMISIA TABACI* (GENN.). D.N. Byrne* and M.A. Houck, Department of Entomology, University of Arizona, Tucson, Arizona 85721.

Using the techniques of discriminant function analysis we determined that there are distinct, although subtle, morphological differences between sweetpotato whiteflies, *Bemisia tabaci* (Genn.), that migrate and those that remain associated with the host plants on which they are reared. Important differences include certain leg and eye characters (e.g. eyes of migrants have fewer facets). Of greatest importance, however, are wing characters such as shape and area. Wing characters are the most convenient as well since wings are more easily handled and require less preparation for microscopy.

#1

H-ORGAN OF LEPIDOPTERAN LARVAE-WHAT IS IT ?

Sudhir Bhargava*, Department of Zoology, Government College, Ajmer, India & H. Kallenborn, Department of Zoology, Universit t des Saarlandes, D-6600 Saarbr cken, FRG.

The newly discovered H-organ of Lepidopteran larvae is supposed to be a neurohemal organ, which is present between suboesophageal and prothoracic ganglia. In *Galleria*, *Lymantria* and *Ephestia* it is present in the larval stage and disappears in the pupal stage. Histologically it consists of large glial cells and channel system and it is quite different from the nerves. Its main innervation is to the prothoracic glands and prothoracic spiracles. Possible functions of H-organ are storage of ecdysone and its release, ion exchange and transportation within the hemolymph or secretion and transportation of substances for metabolism and destruction of prothoracic glands. The association of hemocytes with H-organ also suggests that it may be transporting brain hormone to the prothoracic gland. Histological structure and lack of specific electrophysiology suggests that it is neither functioning like a nerve or neurohemal organ. Electron microscopy also supports the same view.

#2

HOMOLOGY OF THE PHALLUS OR PENIS IN INSECTS.

U.S. Bhatti* and S. Kaur Bhatti, Department of Zoology, I.P. College, Bulandshar (UP), India. 203001.

True nature and homology of the phallus or penis in representative species, such as, *Achoea janata* L. (Lepidoptera), *Polistes olivaceus* (DeGeer) (Hymenoptera), *Aedes aegypti* L. (Diptera), *Dysdercus koenigi* Fabr. (Hemiptera), *Schistocerca gregaria* Forskal (Orthoptera), has been established on the bases of evidences identified and illustrated from their morpho-anatomical and ontogenetical studies. Similarity in the embryonic and or postembryonic source of origin of imaginal discs of phallus, course of their developmental differentiation and elaborate morphogenesis, in each insect species, was taken as the primary and the most reliable operational indicator of homology. The secondary criteria, used in support were: topographical positioning of developing phallus, skeleto-muscular morphology, patterns of innervation, tracheation, and performance of phallus in inseminating the female. Our study documents the fact that homology in male phallic organs of higher insect groups is an intrinsic function.

#3

EFFECTS OF BENZYL OXY JUVENILS ON OVIPOSITION, HATCH, AND GONADAL MORPHOLOGY OF *CORCYRA CEPHALONICA* (STANTON) (LEPIDOPTERA: PYRALIDAE). Sanjib Chakravorty* and Nilanjan Roychoudhury, Department of Zoology, Kalyani University, Kalyani 741235, India.

Larvae and pupae of the rice moth, *Corcyra cephalonica* (Stanton), were treated topically with three benzyl oxy juvenils: 2,6-difluoro-N-(4-(3-fluorophenyl) methoxy) phenyl 7-methyl 7-benzenamine (AI3-63604), 1-(4-chlorophenyl)-2-methyl-3-(4-(phenylmethoxy) phenyl 7-propene-1-one (AI3-63629) and 1-(4-methylphenyl) methoxy 7-4-pentylbenzene (AI3-63701). Emerged adults had significantly low ($P < 0.001$) oviposition and hatching rate and some did not mate. Anatomical and histoarchitectural observations on ovaries and testes of adults with low reproductive performance revealed severe developmental abnormalities and aberrations that varied with the stage treated.

There was no striking difference in the biological activity among the three compounds. Dose difference at concentrations of 100 ug, 50 ug and 10 ug per individual, was not always significant.

#4

MORPHOLOGICAL AND TAXONOMICAL STUDIES ON *PTEROPHOROIDES PERSICAE* (CHOLODK.) (HOMOPTERA: APHIDOIDEA) INFESTING PEACH TREES IN EGYPT. E.T.E. DARWISH*, Plant Prot. Dept., Menoufia University, Faculty of Agric., Shebin El-Kom, Egypt.

Two distinct morphological forms (apterous viviparous and alate viviparous adult females) and larval instars of *Pterophoroides persicae* (Cholodk.) were morphologically and taxonomically studied and described. Keys are given to the apterous, alate viviparous adult females and larvae of all instars on peach trees in Egypt.

The giant brown bark aphid lives in compact colonies on the trunk, the branches and the twigs on the bark of peach trees throughout the whole year; causing malformations. The leaves and branches of the tree below aphid colonies get covered by sooty mould fungi that grow on the excreta.

#5

INTERNAL MORPHOLOGY OF *CULICOIDES VARIIPENNIS* (COQUILLETT) (DIPTERA: CERATOPOGONIDAE). P. M. Denke* and R. A. Nunamaker, University of Wyoming, Laramie, Wyoming, United States of America 82071.

Culicoides variipennis, the primary vector of blue-tongue virus, was examined at the light microscope level to elucidate the general organisation of tissues in the organism. The insects were killed in glutaraldehyde, dehydrated and embedded in LR White embedding medium prior to sectioning with a Reichert-Jung ultratome, at thicknesses ranging from 0.3 micrometers to 0.5 micrometers. The materials were mounted on slides and stained with toluidine blue for maximum contrast. Because of the small size of this insect, it is possible to section the entire insect longitudinally, and examine the distribution of tissues within the body. This longitudinal information and cross-sectional information are presented here.

#6

STROPHANDRIOUS MALE GENITALIA AS AN EVOLUTIONARY TREND AND ITS PHYLOGENETIC SIGNIFICANCE IN SYMPHYTA. S.S. Dhillon, Department of Zoology, Punjab University, Patiala-147002, India.

On the basis of prolonged observations on Indian Symphyta, it is possible to generalize that the two mainstreams comprising the group remain distinct and mutually aloof. The Strophandria which arose monophyletically as a generalized subgroup is more diverse, possesses dense populations occupying variable ecological niches and is adaptively stabler. The Orthandria, on the other hand, seems to represent a fading stock.

The strophandrious situation, resulting in a complex mating behaviour with six well defined stages emerged from a basic instinct: weaker males desiring to escape physical mauling by comparatively stronger females immediately after copulation. This has led to the fixation of parthenogenesis as a regular but partial mode of reproduction resulting in males only. Thus, females could, under will, determine the sex ratio of a population, and this ability ultimately provided adequacy for socializing some apocritans.

#7

CHEMISTRY AND MORPHOLOGY OF THE SCENT GLANDS OF THREE SPECIES OF BRITISH SHIELD BUGS IN THE ACANTHOSOMIDAE FAMILY (HETEROPTERA). C.E. Evans* and B.W. Staddon, Department of Zoology, University College, P.O. Box 78, Cardiff CF1 1XL, U.K.

Results of analyses (gas chromatography, gas chromatography-mass spectrometry) on the secretions of the Juniper Shield Bug *Cyphostethus tristriatus*, the Birch Shield Bug *Elasmotethus interstinctus*, the Parent Bug *Elasmucha grisea* are given. In addition to the primarily defensive metathoracic gland (MG) the three Acanthosomidae species studied also possess a pair of active dorsal abdominal exocrine glands (DGL) in the adults. The constituent compounds of MG and DGL in male and female insects are compared. Investigations of sexual dimorphism in the microscopic epidermal glands in the abdomen of these insects are also reported, and their possible function as pheromone producers is discussed. The natural products and morphology of the Acanthosomidae is compared with that of other Heteroptera in the superfamily Pentatomoidea.

#8

COMPUTER RECONSTRUCTION OF THE ANTENNAL LOBES IN THE BRAIN OF THE HONEYBEE, *Apis mellifera*. D.Flanagan and A.Mercer*, Department of Zoology, University of Otago, Dunedin, New Zealand.

Within the antennal lobes in the brain of the honeybee, antennal sensory neurons synapse with deutocerebral interneurons forming discrete glomerular structures that surround a feltwork of fibres at the centre of each lobe. Information regarding the position and morphology of invariant glomeruli and other easily identifiable structures in the antennal lobes of the honeybee is made readily accessible using the atlas and 3-dimensional reconstruction of the antennal lobes presented in this paper. The atlas has been constructed using computer reconstruction techniques and provides a valuable reference for physiologists investigating the processing of olfactory information in the brain of the bee. It has been used in our laboratory to determine the specific locations of deutocerebral cells identified using immunocytochemical techniques and intracellular injections with cobalt. The structure and physiology of neurons in the deutocerebrum of the bee brain are discussed in a separate paper (1).

(1) D. Flanagan and A. Mercer. Structure and physiology of neurons in the antennal lobes of the honeybee, *Apis mellifera* (oral presentation).

#9

ELECTRON MICROSCOPIC STUDY OF VITELLOGENIN UPTAKE IN THE FOLLICLE OF *DYSDERCUS INTERMEDIUS* (HETEROPTERA: PYRRHOCORIDAE). R.Fleig, F.Dittmann, W.Engels*, Lehrstuhl Entwicklungsphysiologie der Universität Tübingen, Auf der Morgenstelle 28, D-7400 Tübingen.

During vitellogenesis the follicle cells take up hemolymph material by endocytosis, preferentially along their basal sides. The vesicles formed contain vitellogenin, synthesized by the fat body, in low concentration. Within the follicle cells the sequestered vitellogenin is accumulated in endosomes, rER, and Golgi apparatus. Perhaps this yolk precursor material is coupled with compounds produced by the follicle cells themselves. The material is shifted towards the apical side of the follicle cells, where groups of electron-dense Golgi pits fuse to larger vesicles. Finally, the content of these vesicles is exocytosed into intercellular spaces adjacent to the oocyte. There the material is adsorbed mainly by the microvilli of the oocyte, and finally concentrated basally in coated pits. At last the highly concentrated yolk material is incorporated into the oocyte by pinocytosis. Within the oocyte the coated vesicles fuse forming large yolk spheres which represent about 30% of the final egg volume.

#10

MODIFICATIONS OF ENDOPLASMIC RETICULUM IN MALE GERM CELLS OF THE FIREBUG *PYRRHOCORIS APTERUS* L. (HETEROPTERA). J. Godula, Department of Zoology, Jagiellonian University, Krakow, Poland.

Two modifications of endoplasmic reticulum were observed in the male germ cells of *P. apterus* during spermatogenesis: 1) aggregations of regularly packed endoplasmic reticulum-derived tubules which often form paracrystalline configurations (named here paracrystalline tubular complexes); 2) a system of smooth cisternae which in late spermatids transform, as a result of membrane fusion, into electron-dense lamellar envelope surrounding the organelles of the spermatid. The origin of both structures is discussed and the possible role during spermiogenesis suggested.

#11

THE ROLE OF THE CYTOSKELETON DURING GASTRULATION PROBED BY CYTOSKELETON-AFFECTING DRUGS IN *MANDUCA SEXTA*.

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During gastrulation the pyriform germ band develops to an elongated, completely segmented embryo. The transition includes cell rearrangement which presumably involves the cytoskeleton. Several drugs affecting actin and tubulin polymerization as well as RNA translation, DNA transcription and replication were applied in an in vitro system to analyze their impact on gastrulation. The expression of the cytoskeleton was demonstrated by immunohistochemical methods. Inhibition of actin polymerization, RNA translation and DNA transcription resulted in the destruction of the actin frame and stopped gastrulation immediately. Tubulin polymerization blockers could not prevent gastrulation, but the embryos were considerably smaller than controls. All experiments indicate that actin plays a decisive role in gastrulation and that RNA translation and DNA transcription are mandatory.

#12

THRIPS FEEDING: A SEQUENCE OF MOUTHPART MOVEMENTS DURING FEEDING AS DEPICTED BY SCANNING ELECTRON MICROGRAPHS. W.B. Hunter and D.E. Ullman, Department of Entomology, University of Hawaii, 3050 Maile Way, Rm.310, Honolulu, Hawaii, 96822, USA.

Scanning electron micrographs were used to depict the dynamic sequence of mouthpart movements during feeding for two species of thrips (Thysanoptera: Thripidae). Movement of the labial pad and stylets were recorded by immersing feeding thrips into liquid nitrogen and viewing these thrips with scanning electron microscopy. Results revealed a pair of interlocking maxillary stylets able to move independently on a tongue and groove mechanism, a single mandibular stylet and a fan shaped labral pad that unfolds from within the mouthcone. In addition, ten pairs of sensilla were observed on the paraglossae.

#13

REGENERATION OF ANTENNAE IN *RIPTORTUS CLAVATUS* THUNBERG (HETEROPTERA). K.Ikeda* and H.Numata, Department of Biology, Faculty of Science, Osaka City University, Sumiyoshi, Osaka, 558 Japan.

We observed the growth pattern and the cuticular structure of the regenerating antenna with a scanning electron microscope, after cutting at various sites at first instar. The operated antenna grew excessively at each ecdysis after second instar. When the distal segment was removed, the total length of the remaining three segments was about 50% of the normal antenna, although the length regained 84% of the normal antenna as adults. When the first or second segment was cut, a new joint often arose on the segment which grew most excessively. If the distal segment of the operated antenna was longer than a certain value, the segment grew most excessively. If it was shorter than the critical value, however, the second distal segment grew most excessively. Thus the regeneration pattern depended on the length of the remaining antenna after the operation. Nevertheless, for all cutting site, the structures peculiar to the normal distal segment appeared on the distal segment of the regenerated antenna.

#14

BIOLOGY OF EGGS AND EGG ECLOSION IN SOME LAND BUGS (HEMIPTERA:HETEROPTERA). M.Javahery and J.E.McPharlane. Department of Entomology & Lyman Entomological Museum, Macdonald College of McGill University, Ste. Anne de Bellevue, Quebec, Canada H9X 1C0.

Biology of eggs, emergence mechanisms of 1st instar nymph, and egg eclosion of representatives from 15 families of terrestrial Heteroptera of Nearctic and Palaearctic origin were investigated. The influence of food, temperature, R.H., light on pronymphal development were examined. The role of T-shape of egg-burster, micropylar processes, thickness of chorion and operculum in egg eclosion of 28 species were observed.

Food and light did not appear to have a noticeable influence on egg fertility and hatchability. Both temperature and R.H. influence embryonic and pronymphal development. The T-shape of egg-burster was present in all species studied. Light and T-shape of egg-burster influence egg eclosion.

Emergence of 1st instar occurs by the continuous peristalsis which results in lifting the lid of operculum or in rupturing chorion.

#15

A COMPARATIVE STUDY OF THE DIPTERAN CARDIA: EVOLUTIONARY DEVELOPMENT OF MORPHOLOGICAL SPECIALIZATION FOR SECRETING A COMPLEX PERITROPHIC MEMBRANE. David G. King, Department of Anatomy and Department of Zoology, Southern Illinois University, Carbondale, IL 62901, U.S.A.

The cardia is a complex organ found in most higher flies (*Cyclorrhapha*/Schizophora) at the junction between the esophagus and the intestine. In many Nematocera the homologous region is minimally specialized, consisting of little more than a valve-like flap of tissue. In some other Nematocera, many Brachycera/Orthorrhapha, and some Cyclorrhapha/Aschiza, this region is marked by a distinct cell mass, but there is no well-differentiated organ. Among muscoid flies with a well-developed cardia, the pattern of epithelial folds and the number of specialized secretory cell regions differs from species to species.

The sequential phylogenetic addition of various secretory regions within the cardia suggests that each step of cardia evolution may have created new sites for inductive signalling during development, thereby providing new opportunity for epithelial cell differentiation. The end result is an organ adapted for coping with ingested bacteria by secreting a complex multilayered peritrophic membrane which can segregate intestinal functions.

(This research was supported by NIH grant NS18542 and by Southern Illinois University School of Medicine.)

#16

Defense complex in carabids *Harpalus indicus* and *Pheropophus catorei*. Neelima R. Kumar, Department of Entomology and Apiculture, Dr Y.S.Parmar University of Horticulture and Forestry, Solan, P.O.Nauni-173230 (India).

The defense complex in carabids comprises a glandular area, a storage reservoir and an efferent discharge duct. There is a reaction chamber with accessory glands in *P. catorei* absent in *H. indicus*. The secretory cells of the acini are disposed in a complete layer outside the epidermal duct carrying cells of which there is only one in *P. catorei* but several in *H. indicus*. Each secretory cell shows the presence of a specialized secretory area drained by a fine cuticular ductule. The accessory gland of *P. catorei* consists of secretory units - each unit is a bicellular structure composed of a small (S_1) cell and a large (S_2) cell. The S_2 cell contains a special end-apparatus comprised of a felt-work and a cup-shaped secretory area. Cytochemical studies indicate the presence of -SH proteins and 1:2 glycols in the secretion in both. The secretory cells of *H. indicus* also shows abundant lipoidal granules. The secretion in the accessory gland cells abounds in polysaccharides particularly 1:2 glycols. Structural details and cytochemical studies indicate that the columnar cells in the dorsal lobe of the reservoir of *H. indicus* definitely add to the total secretion.

#17

POISON APPARATUS OF THE SLENDER WAISTED WASP *Eumenes dimidiatipennis*. Neelima R.Kumar, Department of Entomology and Apiculture, Dr Y.S.Parmar University of Horticulture and Forestry, Solan, PO Nauni-173230 (India).

The poison gland of *Eumenes dimidiatipennis*, a solitary wasp, was studied and compared to our previous investigations on a colonial wasp, *Polistes hebraeus* (Entomon, 1981). *Eumenes* possesses a bourreletid type of poison apparatus consisting of two free tubules constituting the acid gland and a convoluted gland enclosed inside the reservoir. An efferent discharge duct leads from the reservoir to the sting. The secretory cells of the acid gland in *Eumenes dimidiatipennis* are disposed in two distinct rows around the cuticularized central duct unlike the single layer condition found in *P. hebraeus*. The secretory cells enclose intracellular secretory areas connected by fine intracellular cuticular ductules to the central duct. Even in the cells of the convoluted gland such areas are conspicuously marked.

Cytochemical studies also reveal a make-up different from that of *P. hebraeus*. The secretory granules and vesicles abound in proteinaceous moiety in the acid gland as well as in the convoluted gland. The size and distribution of the secretory granules, vesicles and vacuoles is variable as is also the position and morphology of the nucleus in different cells-both suggestive of an asynchronous secretory cycle.

#18

DEVELOPMENTAL STUDIES OF THE SEX PHEROMONE PRODUCING GLAND IN THE MALE ORIENTAL FRUIT FLIES, *DACUS DORSALIS* HENDEL WITH SCANNING ELECTRON MICROSCOPY. W.Y. Lee* and T.H. Chang. Institute of Zoology, Academia Sinica, Taipei, Taiwan 11529, R.O.C.

The internal morphology of the pheromone Producing gland of *Dacus dorsalis* male insects on 6 to 10 days old pupae and 1,5,10 to 30 days old male flies was studied by the fracturing technique and observed under the Scanning Electron Microscope type Hitachi S-450. Chang. Institute

The secretory sac of the pheromone gland well forms during the 6 days old pupae. The morphology of the epithelial cells of the sac is looked soft, not well developed, cuboidal shape and well arranged. The cells are gradually enlarged and become irregular arrangement while the insect grows. During the maximum frequency of mating behavior on 10 days old male flies, the cells appear much large and many granules attach on the cell wall. After the mating period on 20 days, the cells show as a degenerated appearance. Meanwhile, no any granules can be observed.

#19

IMMATURE STAGES OF *ENDOMYCHUS BIGUTTATUS* SAY (COLEOPTERA: ENDOMYCHIDAE) WITH OBSERVATIONS ON THE ALIMENTARY CANAL. R.A.B. Leschen* and C.E. Carlton, Department of Entomology, University of Arkansas, Fayetteville, Arkansas, U.S.A. 71701

Endomychus biguttatus larvae were reared in the laboratory on *Schizophyllum commune* Fries sporocarps. Egg, four larval instars, pupa and larval alimentary canal were studied. Eggs are covered with hyphal fragments. Larval vestiture consists largely of unusual corbisoid setae. Pharate pupae have five functional spiracles and pedunculate urogomphi. Thoracic and abdominal margins of pupae are densely papillate. The larval alimentary canal consists of a tubular, gradually expanding foregut, ovate enteric caecae, a tubular anterior midgut and saccular posterior midgut, and a recurved hindgut with cryptonephridic malpighian tubules. Presence of four larval instars, egg bursters, and reflex bleeding in adults suggest phylogenetic affinities with Coccinellidae.

#20

COMPARATIVE MORPHOLOGICAL AND HISTOLOGICAL ANALYSIS OF LARVAL DIGESTIVE TRACT OF FIVE SAPROXILOFAGOUS COLEOPTERAN SPECIES FROM HIDALGO, MEXICO. A. Morón, Area de Biología, Depto Preparatoria, Universidad Autónoma Chapingo, Edo. Méx., Carr. México-Texcoco Km. 38.5 C.P. 56230 México.

The external morphology and histology of larval digestive tract of *Derobrachus apterus* (Cerambycidae); *Heliscus tropicus* (Passalidae); *Parisolea pallida* (Melolonthidae); *Zopherus* sp. (Tenebrionidae) and *Orthostethus* sp. (Elateridae) were compared. These species are part of fauna inhabiting fall logs in the cloud forest of Tlachinol, Hidalgo, México. Each one of the referred species showed different adaptations in the digestive tract which help to assimilate the nutrients of wood; *D. apterus* have a larger mesenteron than the other species, may produce cellulolytic enzymes and do not show special structures for simbiotic retention. *H. tropicus* is noticeable for the great number of regenerative nidus in mesenteron, for the presence of rectal glands and for its shorter life cycle. *P. pallida* showed the greatest specialized digestive tract with three rings of gastric caeca in mesenteron which increase the absorption surface, it has a special organ, the fermenting chamber involved in nutrient absorption and retention of simbiotics. Main features of *Zopherus* gut are three spherical protuberances in the hindgut, probably involucrated in retention of food.

#21

HISTOMORPHOLOGY OF THE FAT BODY DURING DEVELOPMENT AND METAMORPHOSIS OF *APIS CERANA INDICA* (HYM.: APIDAE) Neena and J.P. Singh, Zoology Department, Punjabi University, Patiala, India.

Insect fat body represents a physiological tissue which undergoes changes with the changing functional activities. In *A. cerana indica*, it comprises of a single cell type filling the space between viscera and the body wall. The larval growth is accompanied by an increase in the cell size, showing thereby the storage of various energy reserves. The nucleus becomes compact and irregular in shape. In prepupa, the fat cells attain somewhat rounded shape along with the appearance of numerous albuminoid globules of varying size. The fat cells of 1-day old pupa are loose aggregations of granules and oil droplets. It is very difficult to locate the nucleus at this stage. With further development, the walls of some cells rupture. The utilization of energy reserves during histogenesis is quite apparent. The adult fat body has fibrillar cytoplasm with rounded nucleus. The fat cells of workers differ from those of the drones in size only. The phagocytosis of fat cells as a whole by the oenocytes is also seen.

#22

SALIVARY GLANDS OF FEMALE *CULICOIDES VARIIPENNIS* (DIPTERA: CERATOPOGONIDAE): MORPHOLOGICAL CHANGES ASSOCIATED WITH MATURATION AND BLOOD-FEEDING. R.A. Nunamaker*, B.C. Wick and C.E. Nunamaker, USDA-ARS Arthropod-borne Animal Diseases Research, P.O. Box 3965, University Station, Laramie, Wyoming and Department of Veterinary Sciences, Wyoming State Veterinary Laboratory, Laramie, Wyoming USA

The paired salivary glands of *Culicoides variipennis* lie on either side of the esophagus, slightly above and anterior to the first pair of legs. Each gland consists of five small lobes that are attached to the base of a single long lobe. The small lobes are not divided into recognizable regions, whereas the long lobe consists of a short neck, a proximal region and a distal region. A cuticular salivary duct that arises from these lobes joins with its counterpart from the other gland to form a common salivary duct. The fine structure of all regions of the small and long lobes is similar to that of cells having a glandular function in that there is an abundance of endoplasmic reticulum, mitochondria and microtubules. The microtubules most often appear in bundles of linear array and have an ordered appearance. In all regions, epithelial cells are arranged around the salivary duct and are bordered at the base by a basal lamina. The cells are generally flask-shaped, and enclose an apical cavity of varying size containing electron-dense material.

#23

PHOTOPERIODIC CONTROL OF SEASONAL FORMS AND ADULT DIAPAUSE IN *RIPTORTUS CLAVATUS* THUNBERG (HETEROPTERA: ALYDIDAE). H. Numata* and S. Kobayashi, Department of Biology, Faculty of Science, Osaka City University, Osaka, 558 Japan.

We compared two photoperiodic responses expressed as adults in *R. clavatus*. One was the induction of diapause and the other was the determination of seasonal forms, judged by the coloration of the side of thorax. The photoperiodic sensitivity for the former persisted even after adult emergence, although that for the latter was lost after the fourth nymphal ecdysis. The photoperiodic response curves of both responses were bell-shaped and similar, although the seasonal form did not completely correspond with the diapause status individually. Under near-critical photoperiods, however, short-day form adults tended to go into diapause as compared to long-day form ones. Furthermore, temperature modified these two responses in the same way. These results suggest that a common time measurement system is involved in these two photoperiodic responses. On the contrary, the coloration of the ventral plate of thorax was mainly controlled by temperature and a little affected by photoperiod.

#24

HISTOMORPHOLOGY OF SPERMATHECA OF *CTENOLEPISMA LONGICAUDA*. S. G. Pal and Smita Palit*, Department of Zoology, University of Calcutta, 35 B. C. Road, Calcutta 700 019, India.

Spermatheca of *Ctenolepisma longicauda* is an elongated, tubular muscular structure internally lined with cuticle throughout. Histomorphologically its three different zones have distinct epithelial type of cellular arrangements. Apical zone is a secretory chamber; the middle and short collar controls the flow of secretions. Muscular zone is extensive and stores the sperms. Several alveoli participating in secretion are observed in the muscular zone. It is probable that the secretions of the apical zone and the alveoli are different both in contents and nature. Cuticle shows moderately positive reactions towards lipids. The unequal distribution of muscles helps in the conduction and movements of the sperms.

#25

DID EUSOCIAL BEHAVIOR ARISE ONLY ONCE IN THE APIDAE (APOIDEA: HYMENOPTERA)? J.D.Plant* and H.F.Paulus, Universität Freiburg, Institut für Biologie I (Zoologie), 7800 Freiburg, FRG.

Results from a comparative morphological study on the postmentum of bee mouthparts present a new tribal arrangement for the Apidae and pose the above question. Traditional classification implies that eusocial behavior evolved at least 3 times in the Apidae barring social reversion in the Euglossinae. However the morphology of the postmentum in the Euglossinae suggests that they be placed at the base of the family.

The postmentum of bees has often been misidentified as 2 separate sclerites (mentum & submentum). Since a divided postmentum is only found in the Apidae (except Euglossinae) it is considered as a synapomorphy uniting the rest of the Apidae. The plesiomorphic condition, an undivided postmentum, was found in the Euglossinae and all remaining Apoidea. It is proposed that all Meliponini, Bombini and Apini build a monophyletic group. Since they are all eusocial it is parsimonious to state that they probably evolved from a common eusocial ancestor.

#26

MORPHOLOGY OF HEAD OF SOME MEMBRACIDS (INSECTA: HOMOPTERA) AND THEIR BEARING ON CLASSIFICATION. HAFIZ-UR-RAHMAN, Professor of Zoology, Federal Govt. Urdu Science College, Gulshan-e-Iqbal, Karachi-47, Pakistan and IMTIAZ AHMAD, Professor of Zoology Entomology, University of Karachi, Karachi-32, Pakistan.

The Membracid treehoppers are one of the most serious pests, causing great damage to fodder crops, in a large part of the world, particularly in America. Yet their comparative morphology is almost a virgin field of study. Out of 307 genera and 2298 species (Metcalf and Wade 1963) in this family, only one type, *Ceresa bubalus* (now *Stictoccephala bubalus* (Fabr)), has so far been thoroughly studied. A detailed study of 11 genera and 44 species have been under taken.

#27

EXTERNAL MORPHOLOGY OF COCCINELLID (COLEOPTERA) EGGS. C. Ricci*, I. Stella, M.E. Rossodivita, Agric. Entomology Inst., Perugia Univ., Borgo XX Giugno, 06100 Perugia, Italy; B.K. Agarwala Dept. Life Science Calcutta Univ. Agartala, India & C. Czepak, Centro Nacional Pesquisa de Arroz, Feijao Goiania Goias, Brasil.

Chorion structures and morphology of eggs of some species of Epilachnini, Coccinellini, Noviini, Coccidulini, Chillocorini, Platynaspini, Scymnini and Stethorini tribes from different Zoogeography Regions were compared by SEM. Tube-like and trumpet-shaped structures, chorion sculpturing and a peculiar membrane, completely covering each egg of some species were revealed. The tube-like structures are present in all coccinellid eggs but distributed differently: 1) in one or two concentric circles around the anterior pole or at both poles; 2) a ring below the anterior pole; 3) in clusters at both poles. When associated with trumpet-shaped (micropyle structures) they form a rosette-like ring with these. The chorion can be sculpted with polygoid or droplet patterns or irregular shapes. The membrane covering each egg of the species studied is present in those belonging to 4 tribes, absent in those of 3 and either present or absent in another. The micropyle and aeropyle structures project through this membrane. Although it appears strong it is possible to remove it. The function and taxonomic value of these structures is discussed.

#28

THE USE OF X-IRRADIATION FOR DISRUPTION OF POSTEMBRYONIC NEUROBLASTS IN THE THORACIC GANGLION OF *MANDUCA SEXTA* (LEPIDOPTERA: SPHINGIDAE). R. J. Russo, Department of Biology, Indiana Univ.-Purdue University at Indianapolis, Indianapolis, IN, 46223.

The adult CNS of the hawkmoth is composed of two sets of neurons. The first set originates in embryonic development and functions during the larval stage. Some of these larval neurons are modified during metamorphosis and retained in the adult CNS. The second set of neurons is produced by postembryonic neuroblasts which begin dividing during the 3rd larval stadium and differentiate during the pupal stage. Selective disruption of postembryonic neuroblasts would produce adults with a complete CNS except for the progeny of ablated neuroblasts. The 2nd thoracic ganglion was selected for study because of its control over adult legs and wings and has 22 bilaterally paired and 1 unpaired neuroblasts. X-irradiation was used to disrupt postembryonic neuroblasts and block further production of adult-specific neurons. An X-ray machine set at 50 Kev, 22 mA and producing 106 rads/sec at a distance of 12 cm was used for the treatment of Day 1 - 3rd instar larvae. A shield was constructed to collimate the X-rays on the center of the mesothoracic segment. Within the range of 20 - 60 Krads, greater doses produced larger neuronal deficits as assayed in day 1 wandering stage. The nests of neuroblast progeny within the irradiated segment had the normal number of progeny or less than 6 cells within the nest. The small or missing nests seemed random. The irradiated segment was frequently smaller than adjacent segments in the course of development. At higher doses, larval prolegs were lost at the next molt and pupae were malformed in the mesothoracic region. Doses as low as 20 Krads still produced a few disrupted neuroblasts.

#29

MAIN LINES OF ARTHROPOD EVOLUTION: MORPHOLOGICAL EVIDENCE Edward Laidlaw Smith, California Academy of Sciences/ San Francisco State University, San Francisco, CA 94118
Arthropoda is monophyletic. +Trilobitomorpha had post-antennal coxopodites+endites ankylozed into a gnathobase. Arachnomorphs show: preoral appendage elimination making 1st postoral (cheliceræ) antermost, development of carapaces, formation of abdominal phyllopods; several lines became terrestrial independently, w/either/both phyllopod-booklungs, intersegmental tracheae; and reduced compound (lateral) eyes. In Crustacea, mandible coxopodite+endites ankylozed, many developed thoraces, carapaces involving different somites. Bilateral pairs of intersegmental tracheae arose on postoral somites in Myriapoda+Hexapoda, and mandibular telopodite was lost, but coxopodites+endites were uncombined, as still in Myriapoda. In Hexapoda, mandible was ankylozed, Myriapoda became cryptozoic w/loss of ocelli, modification of compound eyes. Mouthparts of Collembola, Protura became invaginated, but leg-like antennae, 4 ocelli, compound eyes on somite III were retained by 1st. In other hexapods, antennae became flagellar, anterior ocelli fused, compound eyes shifted to IV. Aptera (Diplura) also developed invaginated mouthparts, but cerci became flagellar. Archeognatha retained exerted mouthparts, developed flagellar cerci independently. +Monura retained leg-like cerci, but w/Thysanura+Pterygota, labrum is a 2° division, and semipermanent anterior mandible articulation and gonangulum appeared. Ankylozed pteralia developed in 2+ paleopterous lines (+paleodictyopteroids, Ephemera+Odonata) w/early members of 1st w/separate articles permitting wingfolding parallel to Neoptera. Early insects (wingless, winged, larvae) usually had leglike palps, abdominal appendages w/ungues; early pterygotes had 3 pairs of thoracic wings, all movable in immatures unlike recent fauna. Cladograms based on above and other evidence are posted.

#30

#31

TARSAL ADHESIVES MECHANISMS IN COLEOPTERA AND THEIR ROLE IN HOLDING ONTO PLANT SURFACES. N.E. Stork, Dept. of Entomology, British Museum (Natural History), Cromwell Rd., London SW7 5BD, U.K.

Many beetles and other insects bear brush-like pads of adhesive setae on their tarsi to help in walking on plant surfaces. Experiments with living beetles and detailed study of the setal morphology suggest that attachment is due to tarsal secretions and molecular adhesion resulting from the close contact of the setae with the plant surface. Further studies indicate that the peculiar form of waxes on the surfaces of plant leaves as well as trichomes are mechanisms plants have evolved to combat tarsal attachment of some adhesive setae-bearing insects.

#32

INDUCTION OF PRECOCIOUS METAMORPHOSIS BY AN IMIDAZOLE COMPOUND(KK-42) IN THE ARMYWORM, *LEUCANIA SEPARATA* WALKER (LEPIDOPTERA: NOCTUIDAE). K. Tateishi¹, S. Yagi^{2,1} and E. Kuwano³

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3. Department of Agricultural Chemistry, Faculty of Agriculture, Kyushu University, Fukuoka 812, Japan

Effects of an imidazole compound(KK-42) on growth and development in the armyworm, *Leucania separata* Walker, was studied especially in relation to precocious metamorphosis. When the application of KK-42 was started in the 5th instar stage, precocious pupae appeared in the same stage following treatment. In the case of application started in the 4th instar stage, precocious pupae were obtained at the 2nd ecdysis.

Further experiments on threshold size and head capsule width for precocious metamorphosis are discussed in the armyworm.

#33

MONOCLONAL ANTIBODIES REVEAL THE PRESENCE OF ACETYLCHOLINESTERASE VERY EARLY IN THE DEVELOPING OPTIC SYSTEM OF *DROSOPHILA*.

William J. Wolfgang*, Ann Gnagey, and Michael Forte. Vollum Institute for Advanced Biomedical Research, Oregon Health Sciences University, Portland, Oregon.

Acetylcholine (ACh) and acetylcholinesterase (AChE) are present in the central nervous system of insects where they function in neurotransmission. Using temperature sensitive mutants for AChE Hall et al. (Genetics 96:939-965, 1980) demonstrated that placing animals at the restrictive temperature either late in embryogenesis or during metamorphosis resulted in developmental, functional, and morphological defects in the CNS. We have isolated 6 monoclonal cell lines which produce antibodies that bind purified AChE in ELISA assays and recognize AChE in the cell bodies and neuropil of photoreceptor cells in the developing eye 4 days before adult eclosion. In addition their axons growing into the CNS stained intensely in the lamina also stained strongly in the medulla. These results are particularly intriguing because temperature shocks in the mutants during optic development produce defective opto-motor responses.

#34

DIRECTIONAL SELECTION FOR NARROWED OVIPOSITORS IN A LABORATORY STRAIN OF THE MEDITERRANEAN FRUIT FLY (DIPTERA: TEPHRITIDAE). M. Zapater*, Catedra de Genetica, Facultad de Agronomia, 1417 Buenos Aires, Argentina, and S. R. Jones*, The Frost Entomological Museum, Department of Entomology, The Pennsylvania State University, University Park, Pennsylvania 16802, U.S.A.

Directional selection for narrower ovipositors was initiated in a laboratory strain of the Mediterranean fruit fly, *Ceratitis capitata* (Wiedemann). The original laboratory strain oviposited into perforated plastic containers (0.28mm average perforation diameter), while the oviposition substrate utilized by the selected strain consisted of a small-hole mesh (0.21mm average perforation diameter). In the 1st generation, 1 to 5 percent of the original stock successfully oviposited through the narrow mesh substrate, with an increase in successful oviposition in subsequent generations. Ovipositor widths were significantly narrowed by generation 12, and were accompanied by a reduction in width variability. Other morphological characters, including ovipositor length and body size, remained unchanged during the selection process.

#35

THE OCCURRENCE OF ANAL SUCKERS IN ACARIDIDA - ITS RELATION TO SELECTED MORPHOPHYSIOLOGICAL FEATURES OF THE MITES. W. Witaliński, E. Szlendak and J. Godula*, Institute of Zoology, Jagiellonian University, 30-060 Kraków, Karasia 6, Poland.

Analysis of selected features of various Acaridida species suggests that the occurrence of anal suckers is related to the mode of copulation. More primitive, proconiugal copulation (partners directed concurrently) excludes the presence of anal suckers, while retroconiugal copulation (advanced feature, partners directed inversely) prefers their development. On the other hand, the presence of anal suckers in males requires smooth dorsal surface of the female, whereas the absence of suckers is frequently accompanied by rough dorsal cuticle of the female. Other characters like the occurrence and diameter of tarsal suckers and location of aedeagus in male as well as location of copulatory opening in female can also be related to the occurrence of the anal suckers.

#36

A COMPARISON OF THE LARVAL STRUCTURE AND BEHAVIOUR BETWEEN *NEOMICROPTERYX NIPPONENSIS* ISSIKI AND *PARAMARTYRIA SEMIFASCIELLA* ISSIKI (LEPIDOPTERA: ZEUGLOPTERA, MICROPTERYGIDAE). T. Yasuda, Entomological Laboratory, University of Osaka Prefecture, Sakai, Osaka, 591 Japan.

N. nipponensis and *P. semifasciella* coexist in the same habitat. Moths are usually found within about 1m of the forest floor, and closely associated with liverworts. *N. nipponensis* on *Conocephalus conicus* Dum. (Conocephalaceae) and *P. semifasciella* on *Heteroscyphus beschlerlei* (Steph.) (Lophocoleaceae). In the field larvae were found on the underside of the thalli. When the larvae walked, the head of *nipponensis* may be withdrawn so that the head is not visible, but the head exerted in *semifasciella*.

Taken together the structural characteristics of the larvae of *Paramartyria* suggest that it is closely relative to *Neomicropteryx*, and I believe that *Paramartyria* + *Neomicropteryx* is the most likely intergeneric relationship within the *Sabatinca*-group.

EPIDERMIS AND ITS DIFFERENTIATION. M. Locke, Department of Zoology, University of Western Ontario, London, Ontario, Canada N6A 5B7.

This paper shows how insect epidermal cells are peculiarly suited to experiments on problems of general interest in cell biology.

The epidermis of *Calpodes* secretes at least 14 polypeptides apically into the cuticle and 12 different ones basally into the hemolymph. In addition, Arylphorin is secreted both apically and basally. Sequential secretion by the golgi complex may allow for the dichotomy of routing that ends in bi-directional secretion.

The epidermis of Lepidoptera is an epithelium of siamese twin cells caused by the retention of mid bodies from one mitosis to the next. A consequence is that some nuclear and cytoskeletal arrangements are paired, giving evidence for the short term inheritance of structure.

Epidermal cells change their shape and relations to one another under the influence of ecdysteroids at metamorphosis. The movements involve both filopodia and epidermal feet. Filopodia are also easily and almost instantly induced by the experimental separation of cells, allowing the study of their elongation, surface recognition, attachment and contraction.

EPIDERMAL PREPARATIONS FOR ECDYSIS AND THEIR HORMONAL CONTROL. S.E. REYNOLDS, School of Biological Sciences, University of Bath, Claverton Down, Bath, BA2 7AY, UK.

Ecdysis, the shedding of the old cuticle, is a relatively brief event in the moulting cycle. Preparation for ecdysis can be understood in terms of the need to maintain the integument's exoskeletal functions, and to minimise the mechanically vulnerable period of ecdysis.

Chemical stabilization of the new cuticle (sclerotization) is not restricted to the period immediately after ecdysis. Selected regions are sclerotized before ecdysis. These regions are those that have essential mechanical roles during and immediately after ecdysis. This pre-ecdysial tanning is controlled by the declining titer of ecdysteroid moulting hormones.

Digestion of the old cuticle is delayed until late during preparation for ecdysis. Dissolution of the old cuticle is achieved by a cocktail of proteolytic and chitinolytic enzymes in the moulting fluid that acts synergistically to attack the chitin-protein fibre-composite. The expression of these enzymes is again regulated by the declining ecdysteroid titer.

THE EPIDERMIS AND METAMORPHOSIS. J.H. Willis, Department of Entomology, University of Illinois, Urbana, IL 61801, U.S.A.

Cuticular proteins from different anatomical regions and metamorphic stages of *Hyalophora cecropia* have been compared using electrophoresis and partial sequence data. This presentation will summarize the results and conclude that several of these structural proteins are utilized at all three metamorphic stages. Analyses of translation products of epidermal RNA show that the presence of translatable messages underlies the appearance of specific proteins in the cuticle. Hence, structural proteins of the epidermis do not appear to be organized into stage-specific gene sets. What about "regulatory" genes? Published data on the stage- and regional-distribution of transcripts and proteins from oncogenes, pair-rule genes and homeotic genes in *Drosophila melanogaster* will be analyzed to see if any of these "regulatory" genes can be assigned to stage-specific sets. Failure to identify such sets means either that we have not yet identified regulatory genes which specify metamorphic stages, or that regulation, like structure, is based on some kind of combinatorial use of factors rather than on unique stage-specific elements. (Supported by NSF DCB 8607865)

HORMONAL CONTROL OF SEQUENTIAL GENE EXPRESSION IN INSECT EPIDERMIS. L. M. Riddiford, Department of Zoology, University of Washington, Seattle, Washington 98195, USA.

The epidermis of the tobacco hornworm, *Manduca sexta*, makes a pigment, insecticyanin, and a set of endocuticular proteins during each larval intermolt. Expression of the genes for insecticyanin and 3 of these cuticular proteins is suppressed by the rise of ecdysteroid, transiently when juvenile hormone (JH) is present during the larval molt and permanently in the absence of JH during pupal commitment. A 4th cuticular gene is spatially and temporally restricted in its later expression at commitment. During the late 5th instar a small rise of ecdysteroid in the absence of JH initiates expression of several new endocuticular genes which are subsequently repressed permanently at pupal commitment. Thus, JH is necessary for the continued expression of the first set of larval genes, but represses expression of the late larval cuticular genes. A comparison of sequences of these 2 types of cuticular genes shows similarities in the coding regions but little in the 5' regulatory regions. These genes apparently are not directly regulated by ecdysteroid, but may be by JH which binds to a high affinity nuclear receptor in these cells. Supported by grants from NSF and NIH.

HORMONE-INDUCED DIFFERENTIATION IN THE EPIDERMIS J. Fristrom*, R. T. Apple, J. Doctor, D. Fristrom, and W. Wolfgang, Department of Genetics, University of California, Berkeley, CA 94720 USA.

In response to 20-hydroxyecdysone imaginal discs of *Drosophila melanogaster* form the pupal cuticle both in vitro and, during metamorphosis, in vivo. Formation of the cuticle involves sequential deposition of the outer then inner epicuticle followed by the exo- and endocuticles. The proper sequence of cuticle deposition depends on proper hormonal cues. Its successful elaboration may first require modification of the apical surface of the disc epithelium to form an "assembly zone." The inner epicuticle contains chitin-like material, and low molecular weight proteins like those found in the exocuticle. The pupal exocuticle contains chitin and low molecular weight proteins some of which are related to proteins found in larval cuticles. A protein with structural similarities to vertebrate keratin is also synthesized at the time of exocuticle formation and presumably incorporated into the exocuticle. The endocuticle contains chitin and specific high-molecular weight proteins.

BIOCHEMISTRY OF CHITIN. E. Cohen, Department of Entomology, Faculty of Agriculture, The Hebrew University of Jerusalem, Rehovot 76 100, Israel.

Polysaccharides accumulate as intracellular storage nutrients (starch, glycogen, inulin) or are deposited as extracellular supportive components (cellulose, glucan, chitin) in cell walls of plants, algae and fungi, or in the cuticle of arthropods.

Formation of chitin microfibrils is extremely complex and involve a dynamic coordinated interaction of substrate and co-factor molecules with membrane-bound proteins which catalyze the chemical linkages between N-acetylglucosamine units or are associated with extrusion of the nascent polymers. The extruded polymers which crystallize by interchain hydrogen bonding, form the microfibrillar component of cuticles and peritrophic membranes. The periodic formation and degradation of chitin is under hormonal control. Quantitative modulation of chitin synthesis might be regulated at the sites of catalysis and polymer extrusion.

Interference with chitin formation at the catalytic site of the polymerizing enzyme has been demonstrated with the microbial-derived nucleoside-peptide antibiotics. It is speculated that the highly effective insecticidal acyl ureas may act by high-affinity binding to membrane receptor proteins crucial for polymerization or polymer extrusion.

SCLEROTIZATION. S.O. Andersen, Institute of Biological Chemistry A, 13 Universitetsparken, 2100 Copenhagen O, Denmark.

During sclerotization various oxidation products of o-diphenols are incorporated into the cuticle, resulting in a stiffer and more resistant material. Several mechanisms for sclerotization have been suggested, such as quinone tanning, quinone methide sclerotization, and β -sclerotization, and two sclerotization agents have been reported: N-acetyldopamine and N- β -alanyldopamine. General agreement on the importance and validity of the various proposals has not yet been obtained. Some of the available evidence will be discussed, and new results from locust cuticle will be reported.

It is concluded that no single sclerotization mechanism can explain all findings, and that the differences between cuticles from various species indicate that insects have developed several mechanisms for producing a stabilized exoskeleton.

MOLECULAR MECHANISMS OF SCLEROTIZATION. M. Sugumaran, Department of Biology, University of Massachusetts at Boston, Harbor Campus, Boston, Mass 02125.

The exoskeleton of several insects are toughened by a process called sclerotization. For this process, cuticular phenoloxidase is known to provide reactive intermediates. Based on the nature of this intermediate, two different mechanisms have been proposed for sclerotization reactions in the past. The first mechanism proposed by Pryor invokes the formation of quinones from catechols, while the second mechanism calls for a dehydro N-acetyldopamine intermediate. Both the proposed mechanisms will be critically evaluated. Based on our finding that cuticular phenoloxidases isolated from *Sarcophaga bullata*, *Manduca sexta*, *Periplaneta americana* and *Drosophila melanogaster*, catalyze the conversion of certain 4-alkyl catechols to quinone methides, a new mechanism for sclerotization reaction will be presented. The role of quinone methide sclerotization along with quinone and other tanning modes in strengthening the insect cuticle will be discussed.

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CUTICULAR PROTEINS: INQUIRY INTO CELLULAR DIFFERENTIATION DURING METAMORPHOSIS.

D.L. Cox-Foster*, Department of Entomology, The Penn State University, University Park, PA 16802.

Cuticular proteins are a popular model system for elucidating the regulatory mechanisms of cellular differentiation during metamorphosis. In contrast to the concept of stage-specific gene sets, an increasing body of evidence illustrates that cuticular proteins are more related to the functions and properties of the cuticle than to the insect's metamorphic stage. Characteristics associated with differences in cuticular regions include the sets of proteins used, their average isoelectric points, and their post-translational modifications. Results indicate that the genes encoding cuticular proteins and molting fluid enzymes are under temporal and spatial regulation. For example, the *Gld* gene encoding the molting fluid enzyme glucose dehydrogenase is expressed throughout metamorphosis in *Drosophila* in a region-specific manner by epidermis or epidermal derivatives. GLD is secreted during pupariation and is responsible for the operculum formation. Interactions among GLD and cuticular proteins of the puparium will be discussed.

MACROMOLECULAR CHANGES DURING METAMORPHOSIS OF THE INTEGUMENT. P. Wolbert* and F.G. Schäfer, Zoological Institute, University of Würzburg, D-8700 Würzburg, Germany.

In pupae of *Galleria* the switch from pupal to adult expression in epidermal cells occurs during day 1 after pupation, followed at day 2 by a peak of hemolymph titer of ecdysteroids (Ec) and the outset of adult cuticle synthesis. The switch can be prevented by juvenile hormone (JH).

Developmental redetermination and differentiation is correlated with changes in the macromolecular content and synthetic profiles of epidermal cells. The electrophoretic banding pattern of cytoplasmic and nuclear proteins is altered mainly at day 2, whereas changes in the pattern of newly synthesized proteins start immediately after pupation. A few but distinct differences can be observed between animals with or without JH or Ec treatment. In vitro translation reveals, that nearly all mRNA changes occur in untreated animals at day 1. Hormones only influence the time course and not the pattern of the changes.

Macromolecular changes are discussed as part of a general mechanism of reprogramming of the integument during postembryonic development.

PHENOLOXIDASES AND THE INTEGUMENT. F. Michael Barrett, Department of Zoology, University of Toronto, Toronto, Ontario, Canada M5S 1A1.

Three different phenoloxidases have been partially purified and characterized from insect cuticle: a tyrosinase, enzyme A, found in unsclerotized Lepidopteran and Dipteran larval cuticle and thought to be involved in wound repair/melanization; a laccase, enzyme B, from pre-sclerotized cuticle and involved in sclerotization; a second laccase, enzyme C, less well-studied than the others.

In *Lucilia cuprina*, enzyme A is localized in the spiral-like epicuticular filaments where it resides as an inactive proenzyme. Comparable phenoloxidase activity, which may or may not be enzyme A, is also found in multivesicular bodies of epidermal cells from wandering larvae and in subdermal tissue thought to be haemopoietic. Cuticular enzyme A resembles the bacterially-activated haemolymphal phenoloxidase but it is not known whether they share a common origin. In *Lucilia*, cuticular enzyme A can be activated to comparable levels in early and late wandering larvae suggesting that this enzyme is not released into the cuticle for sclerotization of the puparium. However, enzyme B does undergo such an increase appearing in the inner epicuticle and outer procuticle where it, along with enzyme A, appears to become inactive as sclerotization proceeds. This paper examines various questions about these enzymes in insects.

CHEMISTRY AND BIOCHEMISTRY OF INSECT CUTICULAR LIPIDS.

Gary J. Blomquist, Department of Biochemistry, University of Nevada, Reno, Nevada 89557-0014.

The function, chemistry and biochemistry of insect cuticular lipids will be discussed, with particular emphasis on the hydrocarbon components. In addition to their critical role of restricting water loss, the cuticular lipids of some species, particularly Diptera, play roles in chemical communication. Most of the cuticular lipids of many species consist of hydrocarbons, which contain complex mixtures of n-, unsaturated and methyl branched components of 21 to 50+ carbons. The biosynthesis of hydrocarbons occurs by the microsomal elongation of fatty acyl-CoAs which are then converted to hydrocarbon. Methyl branched components arise from the insertion of methylmalonyl-CoA in place of malonyl-CoA during chain elongation. In different species, dependent in part on vitamin B₁₂ levels, either the amino acids valine, isoleucine and methionine or succinate can serve as the precursor to methylmalonyl-CoA. Supported in part by USDA-CRGO grant 87-CRGR-1-2293 and NSF grant DCB-8416558.

INTEGUMENT AS A BARRIER TO INFECTION BY MICROORGANISMS.

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Unlike other insect pathogenic organisms, entomopathogenic fungi normally invade through the host cuticle. However, the arthropod cuticle possesses physical and chemical features which provide constitutive (preformed) and pathogen-induced protection against microbial infections. Constitutive defense mechanisms include surface features e.g. a non-wettable waxy layer and the presence of fungi-toxic compounds in the epicuticle and structural features which like the relatively massive procuticle provide a barrier to pathogens that invade via wounds. Several entomopathogenic fungi breach the procuticle using proteases (chymoelastases). Comparative studies utilizing pre-sclerotized and sclerotized cuticles or chemically modified cuticles have demonstrated that cross-linking of proteins and the presence of protein-chitin bonds reduce the susceptibility of procuticle to proteolysis. Also the protease inhibitors present in some cuticles may reduce degradation. The principle induced defense mechanism is melanization. Melanized cuticles resist infection and degradation by the entomopathogen *Metarhizium anisopliae* largely by inhibition of growth and enzyme production.

METABOLIC INHIBITORS OF EPIDERMAL FUNCTIONS. K.C.

Binnington*, CSIRO, Division of Entomology, Canberra, Australia, 2601 and A. Retnakaran, Forest Pest Management Institute, Sault Ste. Marie, Ontario, Canada P6A 5M7.

Two insecticides which inhibit metabolism in the insect epidermis are diflubenzuron (DFB) and cyromazine (CY). Ultrastructural and biochemical studies on these and other metabolic inhibitors eg. polyoxin D (PX) and aminopterin (AM) with known inhibitory properties provide insights into the mode of action of the insecticides. Larvae of the blowfly, *Lucilia cuprina* when fed on medium containing DFB, CY, PX and AM develop cuticular lesions. The effects of DFB and PX, an inhibitor of chitin synthetase are similar; procuticle which lacks a lamellate structure and contains globular material is secreted but in the case of PX the epicuticle is also affected. An effect on chitin synthesis by DFB is confirmed by reduced incorporation of N-acetyl-D-(1-¹⁴C)glucosamine into cuticle. CY does not inhibit chitin formation but causes epidermal cells to invade cuticle and produce necrotic lesions. The necrosis resembles that caused by AM, an inhibitor of dihydrofolate reductase. This finding, combined with the ability of CY to act as a weak inhibitor of this enzyme, suggests that CY may interfere with nucleic acid metabolism.

SECOND MESSENGER CASCADE IN PTTH ACTION. L.I. Gilbert[†], W.L. Combest, W.A. Smith, V.H. Meller and D.B. Rountree, Department of Biology, University of North Carolina, Chapel Hill, North Carolina, 27599 U.S.A.

Prothoracicotropic hormone (PTTH) is the primary agent regulating the rate of ecdysteroid synthesis by the prothoracic glands. Our studies in vitro on the prothoracic glands of *Manduca sexta* indicate that big PTTH (28 kDa) elicits an increase in cellular cAMP that precedes the increased rate of ecdysteroid synthesis and that both responses require the presence of extracellular Ca^{2+} . Ca^{2+} is not required beyond the level of cAMP formation, the results indicating that Ca^{2+} acts via calmodulin at the level of adenylate cyclase. It is suggested that PTTH may act by controlling a Ca^{2+} channel. Increased cAMP-dependent protein kinase (PK) activity was noted following PTTH stimulation leading to the phosphorylation of a 34 kDa protein, tentatively identified as the S6 protein found in the 40 S ribosomal subunit. S6 is important in the translational control of protein synthesis, the latter being required for PTTH stimulation of ecdysteroid synthesis. The phosphorylation of the 34 kDa protein in the presence of PTTH is inhibited in a dose-dependent manner by juvenile hormone (JH), suggesting an interplay between PTTH and JH in the regulation of prothoracic gland function.

PHOSPHOINOSITIDE METABOLISM IN ARTHROPODS. J.L. McSwain, J.R. Sauer* and R.C. Essenberg[†], Department of Entomology and Biochemistry[†], Oklahoma State University, Stillwater, Oklahoma, U.S.A. 74078-0464.

Many agonists stimulate Ca^{2+} changes in cells by stimulating the hydrolysis of plasma membrane associated phosphatidylinositol 4,5-bisphosphate (PIP_2) to diacylglycerol and inositol 1,4,5-trisphosphate (IP_3). IP_3 is released to the cell interior to function as a second messenger mobilizing intracellular Ca^{2+} . Diacylglycerol stimulates protein kinase C which phosphorylates a specific set of proteins.

Homogenized tick synganglia (brains) when added to isolated salivary glands cause an increase in inositol phosphates. The factor(s) in the synganglion that increases salivary gland inositol phosphates appears to be a peptide. Salivary glands from rapidly feeding ticks produce more inositol phosphates in response to brain factor than salivary glands of slow feeding ticks paralleling the increase in plasma membranes in salivary glands of rapidly feeding ticks. cAMP modulates phosphoinositide turnover suggesting that control of cellular responses by the two second messenger systems is bidirectional.

JUVENILE HORMONE ACTION AND FAT BODY GENE EXPRESSION IN LOCUSTA. G.R. Wyatt, Department of Biology, Queen's University, Kingston, Ontario K7L 3N6, Canada.

The fat body of adult *Locusta migratoria* provides favorable material for studying the molecular basis of juvenile hormone action. Vitellogenin (Vg) synthesis is completely dependent on JH, and is induced in adult female fat body to make Vg the major cellular product. Two Vg genes have been isolated and appear to belong to an evolutionary superfamily with the estrogen-regulated Vgs of oviparous vertebrates. After administration of methoprene to locusts, following a lag of 12-24 hr, their mRNAs accumulate coordinately. In the upstream flanking DNA are two 14-nucleotide sequences that show conservation in the two Vg genes and in a JH-responsive oothecin gene isolated from *Periplaneta* by Pau. Methods are being developed for testing their functional activity as potential JH-response elements. JH effects on other locust fat body products have been found: a 30 kD protein expressed at a low level dependent on JH; an 80 kD and a 19 kD protein expressed constitutively but stimulated by JH; apolipoprotein III (also 19kD) not stimulated by JH. Comparison of the genes for these will help to identify control elements. (Supported by NSERC and US NIH).

REGULATION OF GENE EXPRESSION BY STEROID

HORMONES. J. Fristrom*, R. T. Apple, K. Fechtel, J. Moore, J. Natzle, D. Osterbur, S. Paine-Saunders, and D. Withers. Department of Genetics, University of California, Berkeley, CA 94720 USA.

Imaginal discs of *Drosophila melanogaster* undergo a series of morphogenetic and differentiative events during prepupal development. Several genes whose expression correlates with particular developmental events have been cloned and characterized. The evidence suggesting that the expression of these genes is part of a hierarchical response involving 20-hydroxyecdysone will be discussed

CELL-TO-CELL SIGNALLING IN INSECT TISSUES. S. Caveney, Department of Zoology, University of Western Ontario, London, Canada N6A 5B7.

The physical properties of the cytoplasmic matrix and of gap junctional channels determine the rate and extent of the molecular traffic passing internally among tissue cells. The cytomatrix has low affinity for anionic cytoplasmic metabolites, and a high but reversible affinity for inorganic and organic cations. This would favour the widespread cell-to-cell diffusion of anionic second messengers such as inositol polyphosphates and cyclic nucleotides from their site of production in tissues, but restrict hormone-triggered Ca^{++} spikes to close to sites of Ca^{++} release from intracellular stores. Metabolic compartments may be established in a tissue by regional differences in gap junctional coupling between cells. In the epidermis the gap junction mediated cell-to-cell transfer of hormone induced signals may be modulated by the neurotransmitter L-glutamate, through its electrogenic uptake by a membrane transporter, and by 20-hydroxyecdysone. By interacting with the junctional channels through which they pass intracellular signals such as Ca^{++} and cyclic AMP may in turn modulate channel permeability. Supported by NSERC of Canada.

METABOLIC EFFECTS OF ADIPOKINETIC AND HYPERTREHALOSEMIC HORMONES: THE RELATIONSHIP TO HORMONE FUNCTION. J.E. Steele, Department of Zoology, University of Western Ontario, London, Ontario, Canada N6A 5B7.

The corpus cardiacum is the source of polypeptide hormones which can provoke either an increase in haemolymph trehalose or rise in diacylglycerol. These effects reflect a need for energy or a requirement for building blocks in macromolecular syntheses.

The effect of these hormones on haemolymph trehalose and diacylglycerol is attributable to activation of metabolic processes in the fat body. The activity of hypertrehalosemic hormone has been investigated in greatest detail and will form the major part of this presentation.

The effect of hypertrehalosemic hormone on the fat body is mediated by extracellular calcium. Influx of calcium activates phosphorylase and increases glycogenolysis resulting in an increase in glucose 6-phosphate, the substrate for trehalose synthesis. Stimulation of trehalose synthesis by hormone also decreases glycolytic flux which assists in glucose 6-phosphate accumulation. The decrease in glycolytic flux is explained by changes in the concentration of glycolytic intermediates and the activity of the glycolytic enzymes. The data will show that trehalose synthesis is dependent on tricarboxylic acid cycle activity, which is also the target of a corpus cardiacum hormone

THE AKH/RPCH PEPTIDE FAMILY: STRUCTURES, INTER-RELATIONSHIPS AND FUNCTIONS. G. Gäde, Institut für Zoologie IV, Universität Düsseldorf, D-4000 Düsseldorf 1, Fed. Rep. of Germany.

Peptides isolated from the corpora cardiaca of different insect species and belonging to the AKH/RPCH family have different functions. They are involved in lipid (adipokinetic) and carbohydrate (hypertrehalosemic) release and activate fat body glycogen phosphorylase. Up to now 11 of these peptides are sequenced and the primary structures of these octa-, nona- or decapeptides share some common features. They are blocked at the N- (pyroglutamate) and C-(amide group) termini and at position 4 and 8 there are always Phe and Trp residues, respectively. This peptide family is the largest one known in nature. This review will discuss the structures, structure-activity relationships and evolutionary trends in the different orders of insects.

HORMONAL REGULATION OF DIURESIS. J.H. Spring, Biology, Univ. of Southwestern Louisiana, Lafayette, LA 70504, USA.

Insects, because of their small size and high surface area: volume ratios, face formidable problems of water and ion balance. Water loss is minimized by a number of physical and behavioural mechanisms, but ultimately the homeostatic maintenance of the internal milieu is dependent upon the control of excretion. In every species which has been studied, hormones which affect diuresis have been reported. These hormones, usually low molecular weight peptides, may enhance fluid loss (diuretic hormone; DH) or retard it (antidiuretic hormone; ADH). The application of very sensitive analytical techniques, such as high performance liquid chromatography (HPLC), to the study of DH/ADH's has indicated that they are widely distributed throughout the insect central nervous system, although the most concentrated source, and presumably the main site of release, is the corpus cardiacum. HPLC techniques have also revealed that many species contain more than one DH, with each acting via a different second messenger system and exerting different effects on the Malpighian tubules. The integrated action of multiple DH's, and the overall integration of the secretory and reabsorptive segments of the excretory system represent one of more interesting and least well understood aspects of the endocrine control of excretion.

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DIURETIC HORMONES: PURIFICATION AND POSSIBLE RELATIONSHIP WITH VERTEBRATE HORMONES. C.H. Wheeler and G.M. Coast, Department of Biology, Birkbeck College, University of London, Malet Street, London, WC1E 7HX. UK.

Diuretic hormones are responsible for the control of water balance in insects. Such hormones appear to be released mainly after feeding but also during flight, and after eclosion in lepidoptera. They stimulate the production of primary urine by the Malpighian tubules, which may ultimately lead to increased elimination of water from the insect. Despite their importance in insect physiology and the potential of control of water balance as a target for insecticides, there has been relatively little progress in the chemical characterisation of insect diuretic hormones. We will review methods of isolation and assay of diuretic factors and their possible relationships with vertebrate hormones in an attempt to provide fresh impetus to the structural elucidation of these important molecules.

CHARACTERIZATION, STRUCTURAL RELATIONSHIPS AND BIOLOGICAL ACTIVITIES OF MYOTROPIC PEPTIDES G. Mark Holman*, Ronald J. Nachman, VTERL-ARS-USDA, P.O. Drawer GE, College Station, Tx, USA 77841

It was no accident that three of the first four insect neuropeptides structurally characterized were isolated on the basis of bioassays that measured increases in the contractile activity of insect muscle. Such bioassays are reliable, relatively easy to set up, and the results are obtained immediately. When combined with a purification system utilizing ion-pair reverse-phase HPLC and structural characterization by gas-phase sequencing, such a bioassay can facilitate the rapid isolation and identification of myotropic peptides. We have used such a system to isolate and structurally characterize seventeen myoactive peptides from the cockroach and the house cricket. Four structurally distinct groups are represented. Analog and fragment studies of the peptides have demonstrated the core sequences required for activity and the relative importance of the individual amino acid residues.

ISOLATION AND STRUCTURE OF THE ECLOSION HORMONE OF THE TOBACCO HORNWORM, *MANDUCA SEXTA*. H. Kataoka, R. G. Troetschler, S. J. Kramer, B. J. Cesarin, and D. A. Schooley*, Sandoz Crop Protection, Zeecon Research Institute, Palo Alto, CA 94303

Eclosion hormone was isolated from trimmed pharate adult heads of *Manduca sexta* by an eight step purification procedure using a *Heliothis virescens* in vivo bioassay. The primary structure was determined by sequence analyses of the intact peptide and fragment peptides generated by lysyl endopeptidase, endoproteinase Glu-C, and proline-specific endopeptidase. The nature of the carboxyl terminus as a free acid was elucidated by analysis of amino acids from digestion of the intact peptide with lysyl endopeptidase, which liberated leucine, but no leucine amide. The complete primary structure of *M. sexta* eclosion hormone is H-Asn-Pro-Ala-Ile-Ala-Thr-Gly-Tyr-Asp-Pro-Met-Glu-Ile-Cys-Ile-Glu-Asn-Cys-Ala-Gln-Cys-Lys-Lys-Met-Leu-Gly-Ala-Trp-Phe-Glu-Gly-Pro-Leu-Cys-Ala-Glu-Ser-Cys-Ile-Lys-Phe-Lys-Gly-Lys-Leu-Ile-Pro-Glu-Cys-Glu-Asp-Phe-Ala-Ser-Ile-Ala-Pro-Phe-Leu-Asn-Lys-Leu-OH. This sequence has been analyzed using the computer method of Chou and Fasman for prediction of secondary structure. Also, enzymatic treatment and sequence analyses have provided some information on location of disulfide bonds, which will be discussed.

PHYSIOLOGICAL INTERACTIONS IN HOST-PARASITE SYSTEM AND THEIR IMPLICATIONS FOR BIOLOGICAL CONTROL. K. S. Hagen, Department of Entomological Sciences, Division of Biological Control, University of California, Berkeley, CA 94720

In order to more effectively use parasitoids in biological control of pests, it is essential to properly understand the ecology of plant-herbivore-parasite systems. Consequently the physiological interactions in food chains must be elucidated. These interactions span the entire ontogeny of a parasitoid from locating its potential host-community to accepting and developing in or on its host insect. Recent research, much to be reported by the participants of this symposium, reveal the complexity involved in the regulation of a parasitoid's physiology by its host and the parasitoid's influence on its host. These studies are important in the implementation of biological control because they tell us what factors determine or regulate specificity, synchrony, phenology and chemical ecology of parasitoids with their hosts. *In vitro* culture of parasitoid larvae not only makes it possible to explore more accurately various physiological interactions but also it is important to developing practical production of parasitoids for field release.

PHYSIOLOGICAL INTERACTIONS BETWEEN THE HOST GENUS *HELIOTHIS* AND ITS GUILD OF PARASITIDS. S. Bradleigh Vinson, Department of Entomology, Texas A&M University, College Station, TX 77843.

The effects of a guild of parasitoids on the physiology of a single host genera will be examined using *Heliothis* (Noctuidae:Lepidoptera) as a model. Some parasitoid species utilize a symbiotic virus (polydnaviidae) which is injected into host insects, invades host tissues, and is expressed. In other species the virus appears unable to invade and the parasitoid is unsuccessful. Other species of parasitoids are endoparasitic and not associated with a virus, yet they affect the hosts' physiology, as due the ectoparasitoids. The physiological effects caused by several different parasitoid species in one host system will be compared.

STUDIES ON THE NATURAL AND SIMULATED PARASITISM BY THE ECTOPARASITE *EUPLECTRUS* SPP. (HYMENOPTERA: EULOPHIDAE). T.A. Coudron, USDA, ARS, P.O. Box 7629, Columbia, MO 65205-5001, USA.

Natural and factitious host insects were tested for their response to parasitization by the gregarious ectoparasitoid *Euplectrus plathypenae*. Arrestment of larval molting occurred as a result of both natural and simulated parasitization tests on a large number of insect species. The substances which caused the arrestment of molting in the host was isolated from rhombic crystals located in a gland/reservoir complex attached to the common oviduct of the female parasitoid. The substance is capable of acting directly on the epidermal tissue once in the hemocoel of the host. Ecdysterone and juvenile hormone did not prevent the arrestment of molting.

PHYSIOLOGICAL AND MOLECULAR HOST-PARASITE INTERACTIONS IN THE TOBACCO HORNWORM, *MANDUCA SEXTA*. Nancy E. Beckage^{1,2}, Jeanette S. Metcalf², and Dorothy J. Nesbit². ¹USDA ARS and ²Department of Entomology, University of Wisconsin, Madison, Wisconsin 53706 USA.

Parasitism of tobacco hornworm larvae by *Cotesia congregata* dramatically alters the physiology of host *Manduca sexta* larvae. Analyses using one- and two-dimensional gel electrophoresis indicate that multiple parasitism-specific proteins are induced. A major 33 kilodalton "early" band appears during the initiation of parasitism and is comprised of multiple subunits having isoelectric points in the range of 4.8 to 5.0. This polypeptide is induced by the polydnavirus injected by the parasite into the host. Later, an abundant >100 kilodalton polypeptide (pI = 6.9) is detectable following molting of the parasites to the second instar. Insect growth regulators that inhibit ecdysis of the wasps suppress synthesis of this protein, suggesting it may be produced by mature parasites, or the host's tissues in synchrony with their development. Analyses of hemolymph monophenoloxidase levels, using the rate of conversion of ³H-tyrosine to ³H-DOPA to monitor enzyme activity, demonstrate that activity is significantly depressed during the final stages of parasitism. Characterization of the parasite polydnavirus will also be described.

CONTRIBUTING FACTORS TO REDUCED ECDYSTEROID TITERS IN *HELIOTHIS VIRESCENS* PARASITIZED BY *MICROPLITIS CROCEIPES*. D.L. Dahlman* and D.L. Coar, Department of Entomology, University of Kentucky, Lexington, KY, USA 40546-0091.

Heliothis virescens larvae parasitized by *M. croceipes* stop growing at a specific point in their development just prior to a normal surge in ecdysteroid release. Insufficient ecdysteroid titer is the apparent explanation for this observation. Host tissue is responsive to exogenous ecdysteroid but the prothoracic gland of parasitized larvae only synthesizes insufficient titers of ecdysteroid. In addition, excised prothoracic glands from parasitized larvae can be stimulated to produce ecdysteroid *in vitro* by a PTTH containing fraction from the hemolymph of *Manduca sexta* larvae. Gross morphology and light microscopy show little effect of parasitization on prothoracic glands. Current evidence suggests that ecdysteroid production is inhibited either by insufficient stimulation of the prothoracic gland by the brain neurosecretory materials (PTTH), failure to reduce juvenile hormone tiers at the appropriate time (ie., JH esterase levels may be altered by parasitization) or combinations of these two factors.

ANALYSIS OF POLYDNAVIRUS GENES ASSOCIATED WITH SURVIVAL OF ENDOPARASITES. Davy Jones, Department of Entomology, University of Kentucky, Lexington, KY 40546

Parasitic wasps in the genus *Chelonus* possess a polydnavirus which replicates in ovaries of the female. The virus was purified and virus structural proteins analyzed. Polyclonal antibodies were raised against virus structural proteins, and were used to track entry of the virus into host lepidopteran (*Trichoplusia ni*) eggs during oviposition. The virus was injected late in the oviposition process. Biological experiments showed that late during the oviposition process a material from the female is injected which is necessary for survival of the endoparasite larva. Viral DNA was purified used as a probe in northern analysis of mRNA in parasitized larvae. Several virus encoded transcripts were detected. The results of additional experiments suggested that virus gene expression was required for survival of the endoparasite larva. Supported by NIH GM 33995

CATECHOLAMINE METABOLISM IN IMMUNO REACTIVE INSECTS.
A.J. Nappi (USA)

No Abstract

¹³C NMR STUDIES ON ALTERATIONS IN TCA CYCLE METABOLISM IN *MANDUCA SEXTA* FOLLOWING PARASITISM BY *COTESIA CONGREGATA*. S.N. Thompson*, N.E. Beckage and R.W.-K. Lee, Nuclear Magnetic Resonance Analytical Laboratory, University of California, Riverside, California, USA, 92521.

The predominant flux of carbon from ¹³C2-pyruvate into the TCA cycle in 5th instar control and parasitized *Manduca sexta* larvae resulted from formation of acetyl CoA with label accumulating in C5 of glutamate and glutamine. ¹³C2-pyruvate was directly incorporated into citrate C3 and ketoglutarate C3 but incorporation into the latter was lower in parasitized individuals. Reverse malate-fumarate exchange and isomerization occurred to a greater extent in parasitized insects accompanied by rapid incorporation of label into citrate C4. In contrast, control larvae incorporated relatively higher levels of label into malate C2.

There was little difference in the incorporation of label from ¹³C2-pyruvate into glucose between parasitized and control larvae. In both cases gluconeogenesis resulted in an approximately equivalent distribution of label in C1,6, C2,5 and C3,4. These results suggested that gluconeogenesis does not contribute to the elevated levels of fat body glycogen previously observed in parasitized insects.

IN VITRO REARING OF PARASITOIDS: ROLE OF HOST FACTORS IN NUTRITION. William C. Nettles, Jr. USDA, ARS, Pest Management Research Unit, Southern Crops Research Laboratory, College Station, TX, USA 77841.

Research on *in vitro* rearing of *Eucelatoria bryani* (Diptera) and *Trichogramma pretiosum* (Hymenoptera) indicates that both species of these entomophagous parasitoids are dependent on low molecular weight chemicals present in host insects. Mutations in *Eucelatoria* and *Trichogramma* populations apparently are the reason that these and probably other species of entomophagous insects are dependent on chemicals present in host insects. The mutations are harmless unless attempts are made to rear parasitoids on artificial diets devoid of essential host factors. The rearing of *Eucelatoria*, *Trichogramma*, and at least several other species of important entomophages to control pest insects of great economic importance likely is dependent on the identification of essential factors from host insects and inclusion of these factors in artificial diets.

IN VITRO REARING OF *TRICHOGRAMMA* SPP. AND *ANASTATUS JAPONICUS* ASHMEAD. Li Li-ying*, Liu Wen-hui, Han Shi-chou, Xin Jia-chi & Chen Chao-xian, Guangdong Entomological Institute, Guangzhou, China.

The artificial diets and methods for *in vitro* rearing *Trichogramma* spp. and *Anastatus japonicus* are described. Role of parasites ovipositional behaviour and ovipositor size in success of *in vitro* rearing 11 species of *Trichogramma* is discussed.

POSSIBLE ROLE OF TERATOCYTES OF A BRACONID PARASITOID, *APANTELES GLOMERATUS* L. (HYMENOPTERA: BRACONIDAE). H. Kitano*¹), H. Wago²) and T. Arakawa³) 1), 3) Dept. Biol. Tokyo Gakugei Univ., Koganei, Tokyo 184, Japan 2) Dept. Bacteriol. Saitama Medical School, Moroyama, Saitama 350-04 Japan

A. glomeratus is a gregarious endoparasitoid of the larva of *Pieris rapae crucivora*. Phenol-oxidase (PO) activity in the haemolymph of parasitized and nonparasitized *Pieris* larvae was determined spectrophotometrically by measuring the degree of dopachrome formation in diluted haemolymph with Ca-free saline. PO activity was inhibited in host haemolymph containing young-phase teratocytes, about 45 µm in diameter, but not in that older-phase specimens. The separated teratocytes of the young phase actually suppressed PO activity in haemolymph *in vitro*. Also, essentially the same results were obtained by a new "Single Radial Diffusion Method" using 1.2 % agarose containing 0.01 M dopa. Electron microscopic observation on the morphology of young-phase teratocytes will be undertaken.

ULTRASTRUCTURAL AND FUNCTIONAL MATURATION OF TERATOCYTES OF *APANTELES KARIYAI* (HYM:BRACONIDAE). T. Tanaka, Department of Entomology, Texas A&M University, College Station, TX 77843 and H. Wago, Department of Bacteriology, Saitama Medical School, Moroyama, Iruma-gun, Saitama 350-04, Japan.

Eggs and larvae of *A. kariyai* seem to avoid the host defence reactions by means of calyx and venom fluids (C+V) injected by female in oviposition and the teratocytes (Tc) originated from the embryonic serosal cells 4d post-oviposition. Here, we report that the effect of Tc on phenoloxidase activity (POA) and the ultrastructural changes of Tc with their development. First, both *in vivo* and *in vitro*, POA of parasitized host from 4d to 6d after oviposition was the same level as that of control unparasitized larvae, but decreased greatly from 7d to 10d after oviposition. POA in hemolymph was unaffected by C+V, showing that the decrease of POA was related to functional maturation of Tc. Second, POA-inhibiting factors didn't exist in culture supernatant, but in the cell components. Third, Tc had a lot of rER and vesicles with many microvilli on the surface, which developed with their maturation. Injection experiment of a 1st parasitoid larva, into which Tc from the early (4d) or the late (8d) stage were previously transferred, showed that 1st instar could avoid the host encapsulation and develop up to 2nd instar only in the presence of 4d-Tc and C+V. The inhibition of POA caused by the late Tc may be involved in the parasitoid egression.

RELEASE OF POLYPEPTIDES FROM SEROSAL CELLS OF *BIOSTERES LONGICAUDATUS* (HYM.: BRACONIDAE) *IN VITRO*. P. O. Lawrence, Department of Zoology, University of Florida, Gainesville, Florida 32611, USA.

The ultrastructural and polypeptide compositions of serosal cells from first instars of the solitary endoparasite, *Biosteres longicaudatus* were evaluated. Serosal cells from larvae in pharate pupal hosts (*in vivo*) had similar ultrastructure to those *in vitro*. The presence of numerous endoplasmic reticula indicated a high level of protein synthesis. An electron-dense, protein-like material accumulated along the periphery of the cells and were extruded from the serosa within multivesicular bodies and in fragments of enlarged microvilli.

SDS-PAGE of medium (minus larva and serosa) revealed three major polypeptides, approx. 24, 45, and 80 kilodaltons and 5-6 minor bands of approx. 66-80 kilodaltons. Similar bands occurred in serosal cells and larvae *in vitro* and *in vivo* but were absent from the control medium. A 24 kilodalton subunit was observed in hemolymph from superparasitized host puparia but did not occur in unparasitized individuals. Thus, it appears that first instars of *B. longicaudatus* synthesize and accumulate polypeptides in their serosa from which they are released into the host. The role of these polypeptides are currently under investigation.

ECOLOGICAL PERSPECTIVES ON PARASITOID PHYSIOLOGY: HOST HERBIVORE SUITABILITY. P. Barbosa, Department of Entomology, University of Maryland, College Park, MD 20742, USA.

Plant allelochemicals have been shown to have a significant impact on the survival and development of insect parasitoids. In addition, the effects of allelochemicals on parasitoids depends on the host plant-herbivore-parasitoid association. Most of the experimental variables evaluated have revolved around the physiology of the species involved in the interaction, the allelochemical tested and its concentration. The role of variation among parasitoid individuals, parasitoid populations and in plant chemistry has received less attention. This presentation will consider the ecological implication of the variation in parasitoid response to differing concentrations of different allelochemicals.

DEVELOPMENTAL RELATIONSHIPS BETWEEN *DROSOPHILA* LARVAE AND THEIR ENDOPARASITOID *LEPTOPILINA* (HYMENOPTERA: CYNIPIDAE) AS AFFECTED BY CROWDING. M. Boulétreau*, E. Wajnberg, G. Prévost and P. Fouillet. Génétique des Populations, Université LYON I, 69622 Villeurbanne, FRANCE.

The suitability of *Drosophila* larvae to the development of their endoparasitoid Cynipids has an important genetic component: variations occur between host populations, and we can modify this trait through artificial selection.

Variations occur also between families within the same host population, and express themselves equally towards two sympatric parasitoids, *Leptopilina boulardi* and *L. heterotoma*.

Crowding in hosts is another important factor, which improves the rate of success of both parasite species, smoothes out differences between host families, and between parasite species which then equally thrive.

Moderate crowding has very different effects on unparasitized and on parasitized *Drosophila* larvae, as summarized in the table.

	<i>unparasitized</i>	<i>parasitized</i>
total viability	unaffected	increased (>100%)
adult size	smaller flies (-10%)	smaller wasps (-40%)
devt. time	longer (+30%)	shorter (-10%)

HOST SIZE: WHAT DOES IT MEAN FOR AN APHID PARASITE? M. Mackauer*, M. T. Irvine and R. Sequeira, Centre for Pest Management, Simon Fraser University, Burnaby, British Columbia, Canada V5A 1S6

Most hymenopterous parasites of aphids oviposit in several instars and morphs of their host(s), differing in size. Aphid size, which is a function of age, is a useful index of host quality. Using examples from several species of Aphidiidae and Aphelinidae, we show that several fitness components are correlated with host size. Parasite size (but not longevity) is determined by host size at the time of parasitization and the host's potential for growth subsequent to attack. Size is correlated with a female's (but not necessarily a male's) potential fecundity. Host size is also implicated in behavioral interactions that determine host choice and offspring sex ratio.

INTERRELATIONSHIPS BETWEEN EGGS AND FIRST INSTAR LARVAE OF *ERETMOCERUS* SP. AND ITS HOST, *BEMISIA TABACI*. D. Gerling, and T. Orion, Department of Zoology, Tel Aviv University, Ramat Aviv 69978, Israel.

Eggs of *Eretmocerus* sp. are laid under the nymphs of the whitefly, *Bemisia tabaci* in the immediate vicinity of the mouthparts and legs. The 2nd and 3rd instars are preferred for oviposition. *Eretmocerus* eggs hatch after about 3 days but their larvae do not penetrate the host before it has reached the 4th instar. The penetration hole is 65 µm in diameter, approximating that of the pear-shaped larva (63 µm). Penetration takes about 24 hours and is associated with the cessation of *B. tabaci* pupal development.

The link between the parasitoid larva and the whitefly probably starts shortly after hatching when the former pierces the venter of the latter with its sharp mandibles. This includes the transfer of nutrients from the host to the parasitoid together with information about the host's state of development. It may also include the transfer of development-inhibitors from the parasitoid larvae to the whitefly.

DEVELOPMENTAL SYNCHRONY BETWEEN THE POLYEMBRYONIC PARASITOID *COPIDOSOMA FLORIDANUM* AND ITS HOST *TRICHOPLUSIA NI*. M. R. Strand, Department of Entomology, University of Wisconsin, Madison, Wisconsin 53706, USA.

Trichoplusia ni parasitized by the polyembryonic egg-larval parasitoid *Copidosoma floridanum* attained significantly larger final weights and head capsule diameters than unparasitized controls, but did not undergo a supernumerary instar. The critical size for molting of parasitized and unparasitized hosts did not differ. Development of *C. floridanum* was synchronized with that of the host. The polyembryonic phase of development began during the host egg stage and continued through day 2 of the penultimate instar. Coincident with the host molt to the ultimate instar, embryogenesis of the *C. floridanum* reproductive larvae began. Conversely, precocious larva embryogenesis began during the host first instar, and ceased during the penultimate instar. Data from manipulatory experiments and measures of host hormone titres suggest that *C. floridanum* embryonic development is influenced by hormone titres of host origin.

DEVELOPMENT REGULATION OF PSEUDOPERICHAETA NIGROLINEATA (DIPTERA, TACHINIDAE) BY ITS HOST OSTRINIA NUBILALIS (LEPIDOPTERA, PYRALIDAE). S. Grenier *, A. Ramadhane and G. Plantevin, Laboratoire de Biologie Appliquée-INRA, Bât.406, INSA, 20 av. A. Einstein, 69621 Villeurbanne Cedex - France.

Pseudoperichaeta nigrolineata Walker is a polyphagous species attacking the European corn borer Ostrinia nubilalis Hübner, and which can be reared in the alternative host Galleria mellonella L. We have shown previously that in G. mellonella, a part of the parasitoid larvae show a delayed development due to an arrest of the growth in the middle of the second larval instar. The host physiology is the main factor controlling the arrest of development. The ecdysteroid levels, are related with the arrest.

In O. nubilalis, acute analysis of the phenomenon was conducted by studies of the development of P. nigrolineata in host with or without diapause. The same arrest of growth of the parasitoid at a weight near 1mg, in the middle of the second instar, was also observed in diapausing host. At diapause break of O. nubilalis, the parasitoid resumes its growth and pupariates. We also showed that a good synchronization exists between host and parasitoid larval developments, even in non diapausing hosts. There are four phases of the parasitoid development which would appear to require a "signal" from the host (biochemical composition, Ecdysteroid or Juvenile Hormone levels) : these phases can be related with physiological events occurring in host: 1- the start of the growth of newly hatched parasitoid larvae and the 3/4 larval ecdysis of the host, 2- the first moulting of the parasitoid and the 4/5 larval ecdysis of the host, 3- the growth resumption of the parasitoid instar II (weight about 1mg) and the small rise of the ecdysteroid level in the middle of host instar 5 or at diapause break, 4- the second parasitoid moulting and the larval-pupal apolysis of the host. Experiments of ligation, hormone injection or transplantation were conducted to determine the signals involved.

INFLUENCE OF A HOST HEMOLYMPH PROTEIN IN STIMULATING EARLY EGG DEVELOPMENT IN MICROPLITIS CROCEIPES. P.D. Greany*, W.R. Clark, and S.M. Ferkovich. U.S. Department of Agriculture, Agricultural Research Service, P.O. Box 14565, Gainesville, FL 32604.

Preggerband eggs of Microplitis croceipes were found to be dependent upon a host hemolymph protein for initiation of embryogenesis in vitro in a basal tissue culture medium. Procedures for isolation, characterization, and bioassay of this egg development stimulating protein (EDSP) from hemolymph will be presented, along with elucidation of its biosynthetic source and comparative data on its abundance in permissive vs. non-permissive hosts.

PHYSIOLOGICAL RELATIONSHIP BETWEEN A DIAPAUSING ENDOPARASITOID (Ascogaster quadridentata) AND ITS DORMANT HOST (CYDIA POMONELLA). J.J. Brown, Department of Entomology, Washington State University, Pullman, WA 99164-6432.

The facultative diapause of Ascogaster quadridentata depends upon its host's development. Laboratory reared hosts (25°C), can be programmed for continuous development at 16L:8D, or induced into a development pause at 12L:12D. A parasitoid larva developing in a host reared in 16L:8D undergoes continuous development and consumes its victim before the host can pupate. A host reared under short day conditions ceases development in its fourth stadium. The parasitoid larva overwinters in a true diapause, within its dormant host.

Dormancy of both the host and parasitoid is due to a failure of the host's endocrine system. Upon transfer of the host from dormancy maintaining to terminating conditions, a hemolymph-borne host cephalic substance is released. Parasitoid larvae respond to the host cephalic factor, and/or secondary host substances released in response to the cephalic factor, by increasing their body size and molting into their second stadium. A discussion of neuroendocrine interaction explaining dormancy in both species will be presented.

EFFECTS OF HOST HEMOLYMPH ON REGULATION OF PROTEIN SYNTHESIS DURING EMBRYONIC DEVELOPMENT OF THE ENDO-PARASITOID MICROPLITIS CROCEIPES (BRACONIDAE). S.M. Ferkovich*, and C. Dillar, USDA/ARS, Insect Attractants, Behavior & Basic Biology Research Laboratory, Gainesville, FL, 32604 USA.

Regulation of protein synthesis was studied during embryogenesis after oviposition in its host, Heliothis zea (Boddie) and was compared with that in eggs collected from an artificial oviposition substrate prepared from host hemolymph and agarose. The effects of hemolymph fractions and juvenile hormone on protein synthesis in vitro will be discussed.

PHOTOTOXICITY IN RUTACEAE: VARIATIONS ON A THEME. M.R. Berenbaum, Department of Entomology, University of Illinois at Urbana-Champaign, Urbana, IL 61801-3795 USA

Plants in the genus *Zanthoxylum* contain not fewer than five biosynthetically distinct classes of phototoxins. These include furanocoumarins, pyranocoumarins, furano-quinoline alkaloids, beta-carboline alkaloids and benzyl-isoquinoline alkaloids. In terms of chemical properties, these phototoxins differ in their mode of action, their active spectra and their polarity. In terms of biological activity, these phototoxins also differ in their efficacy against herbivorous insects in various taxa. Despite convergence on light energy as an activating mechanism, proliferation of biosynthetically distinct phototoxins may enhance protection against differentially adapted specialists. The presence of a diverse array of phototoxins may account at least in part for the relatively unique fauna of the family Rutaceae.

TOXICOLOGICAL MECHANISM OF ALPHA-TERTHIENYL ACTION ON *MANDUCA SEXTA* (L.) (SPHINGIDAE) L. Fernandez, L. Swain and K.R. Downum*, Dept. of Biological Sci., Florida International Univ., Miami, FL 33199.

Alpha-Terthienyl (alpha-T), a common phytochemical constituent in members of the Asteraceae (sunflower family), mediates pronounced biocidal effects toward a variety of organisms in the presence of UV-A irradiation (320-400 nm). The biocidal action of this plant metabolite in model unicellular systems has been shown to result from the generation of excited oxygen species (i.e., singlet oxygen ($^1O_2$)) which can result in lipid peroxidation and protein crosslinking among other subcellular effects. Recent work suggests that similar types of cellular damage is inflicted on multicellular organisms (i.e., *Manduca sexta*) following topical treatment with alpha-T/UV-A. Details of studies which demonstrate crosslinking of integument proteins and inactivation of integument-associated enzymes will be discussed.

NATURAL DITHIOCYCLOHEXADIENES AND SULFUR-DERIVATIVES AS PESTICIDAL AGENTS. E. Rodriguez, Phytochemical & Toxicology Laboratory, University of California, Irvine, California 92717, U.S.A.

Recently we isolated a series of dithiocylohexadiene constituents named the thiarubridines from *Aspilia* and other species of the Asteraceae. The thiarubridines are of considerable interest because of their use as anthelmintic agents by wild chimpanzees and native peoples of Canada and Africa. Entomological studies in our laboratory have also demonstrated that the dithiocylohexadienes are insecticidal to lepidopteran pests. Recent studies by nematologists at the University of California, Riverside also suggest that the compounds are nematocidal.

Our findings suggest that the thiarubridines are effecting hormonal production in the larvae. In this presentation, the chemistry, biological and pesticidal activity of sulfur-containing acetylenic compounds will be discussed.

TOXICITY AND FATE OF ACETYLCHROMENES IN INSECTS M.B. Isman*¹ and P. Proksch² (¹University of British Columbia, Vancouver, Canada; ²Technische Universität, Braunschweig, West Germany)

Acetylchromenes (benzopyrans), major natural constituents of the desert sunflower *Encelia*, are insecticidal to a wide range of insects. Structure-activity relations determined via a residue-contact bioassay against the variegated cutworm (Noctuidae) and by topical administration to the migratory grasshopper (Acrididae) and the milkweed bug (Lygaeidae), have established that encecalinal and its unsubstituted analogue demethoxyencecalinal are significantly more toxic than the demethyl derivative or other analogues possessing free hydroxyl groups. Investigation of the metabolism and excretion of chromenes in the grasshopper resulted in the isolation of several hydroxylated metabolites, all of which appear to represent detoxication products, based on subsequent bioassay. Benzofurans, closely related compounds also present in *Encelia*, are not toxic, and appear to antagonize the toxicity of chromenes in certain circumstances. The natural role of these substances in plant defense against herbivory remains unresolved.

ANTIHERBIVORE MECHANISMS IN THE MELIACEAE. D.E. Champagne*, G.H.N. Towers¹, and M.B. Isman², Departments of Botany¹ and Plant Science², University of British Columbia, Vancouver, B.C., Canada V6T 2B1

Factors potentially involved in plant defense, including leaf toughness and the production of anti-insect phytochemicals, have been examined in over twenty species of Meliaceae. Results to date indicate that slow-growing rainforest species appear to invest in mechanical defenses over chemical factors. Other taxa, particularly those with rapid growth, have less tough leaves and rather elaborate an array of anti-insect phytochemicals including limonoids and amides. The defensive chemistry of some previously unexamined species will be presented. The toxicology of azadirachtin, the most active limonoid, will be discussed with reference to three model insects: the migratory grasshopper, *Melanoplus sanguinipes*, the variegated cutworm, *Peridroma saucia*, and the milkweed bug *Oncopeltus fasciatus*. The comparative bioactivity of several other limonoids will also be discussed.

PHYTOCHEMICAL MECHANISMS OF RESISTANCE TO MAIZE FEEDING INSECTS. B.J.R. Philogène & J.T. Arnason, Dept. of Biology, Univ. of Ottawa, Ottawa, Ont., CANADA K1N 6N5

The use of resistant plant varieties to reduce crop loss caused by insects is one of the most effective and environmentally acceptable methods. Resistance in maize is expressed both in the plant against phytophages like the European corn borer (ECB), *Ostrinia nubilalis*, and in the grain against weevils like *Sitophilus zeamais*. Hydroxamic acids contribute significantly to reduction of borer damage. We will examine the effects and mechanism of action of MBOA and DIMBOA on ECB. The adaptation, rates of excretion, the accumulation and metabolism which the ECB has developed to deal with these toxicants will also be discussed.

In the second part, we will discuss resistance factors identified in maize seeds from existing collections of CIMMYT. We have discovered that a strong correlation exists between resistance *in vivo* and phenolic content of the grain. Ferulic acid was found to play a major role as a leading deterrent in maize to consumption by *Sitophilus zeamais*.

The difference in resistance characteristics to ECB and insect infestations allows an overview of the origin of resistance in maize and a better characterization of germplasm resources.

CUTICULAR PERMEABILITY AND WATER BARRIERS: A CURRENT WORKING MODEL. N.F. Hadley, Department of Zoology, Arizona State University, Tempe, Arizona 85287-1501 USA

Although the hydrophobic nature of the arthropod cuticle likely involves all recognized layers and several types of chemical compounds associated with these layers, lipids deposited on the surface and/or impregnated within the epicuticle provide the principal barrier to water efflux in most terrestrial arthropods. Indeed, strong correlations have been demonstrated between the molecular composition and architecture of surface waxes, especially hydrocarbons, and their barrier effectiveness. *In vivo* measurements of cuticular permeability indicate that water flux can vary regionally in the same individual due to differences in cuticle thickness, lipid composition, or the presence or absence of special water-conducting pores. Cuticle hydration state, which is determined predominantly by the endocuticle, may influence transcuticular water flux; however, there is contrasting evidence as to what extent, if any, the epidermis controls the water content of the cuticle or, for that matter, contributes to the barrier properties of the cuticle.

EPIDERMAL FUNCTION DURING THERMOREGULATION IN CICADAS. E.C. Toolson (USA)

No Abstract

ACTIVE ABSORPTION OF WATER VAPOUR : AN OVERVIEW. J. Noble-Nesbitt, School of Biological Sciences, University of East Anglia, Norwich NR4 7TJ, England.

Many mites, ticks and insects from several different orders have independently evolved mechanisms for the absorption of water from the vapour phase of the air, down to relative humidities as low as 43%. The shared problem is environmental water shortage. Both oral and rectal systems exist. Epithelial mechanisms, for the majority, and non-epithelial systems have been proposed.

The non-epithelial oral mechanism of the desert cockroach *Arenivaga* depends on a dense mat of fine cuticular hairs on the hypopharynx. Psocids rely on the hygroscopic nature of concentrated saliva extruded from their salivary glands to entrain vapour. Both systems require cibarial or pharyngeal suction to draw the fluid into the gut.

In *Tenebrio* an epithelial cascade system draws water from the vapour phase of the rectal lumen into the lumen of the cryptonephric Malpighian tubules, and is apparently driven mainly by active KCl transport from the blood into the tubule lumen via specialised leptophragmal cells.

Specialised rectal sac absorptive epithelial cells containing a dense array of rod-like mitochondria closely associated with deeply infolded apical plasma membrane, are found in the anterior sac of the rat flea larva and evaginated posterior sacs of the firebrat, *Thermobia*.

ACTIVE UPTAKE OF ATMOSPHERIC WATER VAPOUR IN THE COURSE OF TICK DEVELOPMENT AND FURTHER EVIDENCE OF THE MECHANISM. O. Kahl and W. Knülle*, Institut für Angewandte Zoologie, Freie Universität Berlin, D-1000 Berlin 41, FR Germany.

Active uptake of water vapour from subsaturated air via the oral route is well established for unfed ticks. Contrary to current opinion this was also shown for certain engorged immatures and also for teneral *Ixodes ricinus* (L.). They display a regulative capacity for compensating water losses at supra-equilibrium humidities as unfed ticks do. The capability of actively absorbing vapour is present soon after detachment and persists to the early pharate phase, a period which in diapausing specimens may extend up to several months. Net uptake of vapour is not possible during the pharate phases when old salivary gland alveoli disintegrate, new ones are formed, and the oral apparatus of the pharatus has no direct access to the ambient air. Tick salivary glands, in particular the agranular alveoli, have been incriminated as being the source of the vapour absorbing secretion. Gross-morphologically agranular alveoli appear intact in all phases during which *I. ricinus* is capable of actively absorbing vapour, whereas the granular alveoli strongly atrophy soon following detachment. This provides further evidence for a decisive role of agranular alveoli in producing the secretion involved in vapour uptake.

ELECTROLYTE SECRETION BY MALPIGHIAN TUBULES. Klaus W. Beyenbach, Dept. and Sect. Physiology, Cornell University, Ithaca, N.Y. 14853.

Malpighian tubules of insects share in common the secretion of cations and anions by respectively active passive transport mechanisms. In Malpighian tubules of *Aedes aegypti* we have studied transport across the membranes of principal cells using microanalytical and electrophysiological methods. The basolateral membrane of the cell offers a ouabain-sensitive Na/K pump and bumetanide-sensitive Na-K-Cl cotransport for K entry and conductive channels for K exit. Na enters the cell via amiloride-sensitive Na/H exchange and a cAMP-regulated Na conductance. Some Na is returned to the hemolymph via the Na/K pump. Cl enters via bumetanide-sensitive Na-K-Cl cotransport and SITS and DIDS-sensitive transport mechanisms. The apical membrane provides an electrogenic cation pump which appears to be coupled to apical membrane Cl conductance such that pump rates are matched to Cl conductance and the electrodiffusive exit of Cl. As a result apical membrane voltage is constant over a wide range of NaCl and KCl secretion rates. The transport activities of these basolateral and apical membrane components vary with the physiological state of the cell under the control of cAMP, mosquito natriuretic peptide, and natural or synthetic insect neuropeptides.

MALPIGHIAN TUBULE ACTION AS REVEALED BY DRUGS, TOXINS AND ANOXIA. Simon Maddrell, AFRC Unit, Department of Zoology, Cambridge University.

Malpighian tubules of *Rhodnius prolixus* transport fluid at very high rates when stimulated by the insect's diuretic hormone or by hormone mimics. In the absence of a stimulant, fluid secretion is 100-1000x slower. In this latter state, activity of a ouabain-sensitive Na/K pump can be detected. Radioactive ouabain binds only to the basolateral surface. Bumetanide-sensitive Na-K-Cl cotransport also occurs on this surface. The 27,000 M_r bacterial endotoxin from *Bacillus thuringiensis* var. *israelensis* affects rapid fluid secretion at all concentrations higher than 4×10^{-8} mol l⁻¹. The kinetics of the effect suggest a new model for toxin interaction with the cell in which a complex of several toxin molecules is required to initiate damaging effects. Electrical measurements of the trans-epithelial potential difference under conditions of substrate &/or oxygen starvation show large oscillations.

ADAPTIVE NEUROENDOCRINE REGULATION OF CUTICULAR WATER LOSS
J. Noble-Nesbitt, School of Biological Sciences,
University of East Anglia, Norwich NR4 7TJ, England.

The brain and terminal abdominal ganglion (TAG) of the cockroach, *Periplaneta americana*, produce water loss promoting and restricting factors according to the insect's physiological state of water balance. The system responds rapidly to environmental change.

Rapid restriction following transfer of fully hydrated cockroaches to low humidity is brought about by the brain restricting factor; longer-term restriction can be accomplished in the presence of TAG restricting factor alone, as in decapitated specimens, which initially have a higher rate of loss than intact insects. Restriction of cuticular water loss is an adaptive response to environmental conditions of desiccation or water-stress, and cumulatively increases as the time under desiccation or water-stress lengthens, whether in isolation or culture conditions. Decapitation has little effect once this low-loss state is established.

The TAG promoting factor is primed by and acts with, or releases more of, the brain promoting factor. Promotion of cuticular water loss may be an efficient means of excreting water when in excess to the body's needs.

These neuroendocrine factors may cause changes in the waterproofing properties of the epicuticular lipids.

Acid/base transport in the hindgut of the desert locust, *Schistocerca gregaria*. R.B. Thomson*, J. Speight, N. Audsley, R. Lechleitner, and J.E. Phillips. Dept. of Zoology, University of British Columbia, Vancouver, B.C.

On the basis of gut pH profiles in a number of terrestrial insects, it has been suggested that the hindgut may play a general role in pH regulation. This assertion has been investigated using a variety of in vivo and in vitro techniques on a representative terrestrial insect, the desert locust. The present study confirms the existence of significant transepithelial pH gradients in the locust hindgut (lumen acid) and demonstrates that both the ileum and rectum are capable of significant rates of luminal acid secretion. In vitro experiments with isolated recta indicate that the pH gradient is largely due to an active, electrogenic H^+ secretory mechanism located in the apical membrane of the rectal epithelium. Moreover, the rectum is also capable of significant rates of NH_4^+ secretion and HCO_3^- reabsorption. In vivo rates of rectal acid secretion appear to reflect the pH status of the animal; however, in vitro studies suggest that rectal acidification is directly modulated by haemolymph pCO_2 and circulating hormonal factors rather than haemolymph pH per se. In conclusion, the hindgut appears to play a significant role in pH regulation in the desert locust by controlled excretion and reabsorption of H^+ , NH_4^+ , and HCO_3^- .

POTASSIUM TRANSPORT IN THE LEPIDOPTERAN MIDGUT GOBLET CELL.

J.A.T. Dow* & J.M. Peacock, Department of Cell Biology, University of Glasgow, Glasgow G12 8QQ, Scotland.

The midguts of larval lepidoptera transport potassium actively and electrogenically from blood-side to lumen side. Electrically, this transport is the most active known, generating TEPs over 150 mV (gut lumen positive) and SCCs greater than 1 mA/cm². The potassium transport is located in the apical membranes of a unique "goblet cell".

This transport has traditionally been argued to represent a specialised excretory adaptation to a uniquely high dietary potassium loading. However, the morphology of the goblet cell renders it highly unsuited to a role in excretion. In an alternative model, the cavity is considered to be an electrically isolated and highly polarised compartment, in which a very high pH (the highest in biology, at over 12) can be generated.

Microelectrode impalements of individual, selected goblet cavities, in the middle midgut region of larval *Manduca sexta* midgut revealed that the cavities were not isopotential with the apical lumen, as had been previously suspected, but were significantly more positive than any other compartment; the degree of polarisation being proportional to the transepithelial pd. The cavities were tight to the low molecular weight fluorescent marker, Lucifer Yellow CH. Both of these properties were as expected for the high-pH model of goblet cavity function, but would be hard to reconcile with the excretory model.

It has been possible to enzymically dissociate midgut cells, allowing single cell studies to be performed. Both cell types display their characteristic morphologies after isolation. It has also been possible to distinguish goblet and columnar cells on the basis of their fluorescence with acridine orange. Goblet cavities stain bright orange or metachromatically red, whereas columnar cells stain green. Additionally, the staining of goblet cells, but not the columnar cells, is sensitive to the transport competence of the cells. This raises exciting possibilities, both for cell separation and for the probing of goblet cavity function with fluorescent dyes.

TRANSPORT ADAPTATIONS OF MIDGUT CELLS FOR A HIGH POTASSIUM ENVIRONMENT. D.F. Moffett, Department of Zoology, Washington State University, Pullman, WA U.S.A. 99164-4220

The high- K^+ diet of lepidopteran larvae presents a problem of K^+ balance; the fraction of absorbed K^+ that is not incorporated into the growing animal must be excreted. The midgut has been regarded as important in this process. Initially, research focused on the lumen-directed apical electrogenic K^+ pump of the specialized goblet cells. Recent studies revealed K^+ -coupled amino acid absorption, alkalization of the contents of anterior and middle midgut with reacidification in the posterior midgut, and active absorption of Cl^- from posterior midgut. In goblet cavities of posterior midgut, K^+ , Cl^- and H^+ are all out of electrochemical equilibrium with respect to the luminal solution and the cytoplasm, indicating active transport mechanisms for these solutes in the goblet cavity apical membrane. Carbonic anhydrase localization on the apical membrane of columnar cells suggests that $Cl^-HCO_3^-$ exchange might also occur at that site. The goblet cavity presents an energy barrier to K^+ transport, but may serve as a buffer to protect gradient-sensitive apical membrane processes from the ionic composition of the gut contents. Supported by NSF DCB 8316739

ISOLATION OF THE ACTIVE COMPONENT IN TRANSEPITHELIAL CATION TRANSPORT OF INSECT MIDGUT. H.Wieczorek*, U.Klein, M.Schindlbeck, H.Schweikl, S.Weerth, Zoologisches Institut der Universität, Luisenstraße 14, D-8000 München 2, Federal Republic of Germany.

The vanadate- and azide-insensitive ATPase activity in purified apical membranes of goblet cells from *Manduca sexta* midgut displays typical properties of active cation transport (Wieczorek et al. 1986, BBA 857: 271-281).

Membrane bound ATPase activity is solubilized with $C_{12}E_{10}$ and purified in an one step-procedure by centrifugation in a sucrose density gradient. The subunit pattern of the purified enzyme in SDS-PAGE consists of five major bands ranging from 17 to 70k and resembles strongly that of proton pumping ATPases from intracellular membranes.

Vesicles obtained from partially purified membranes exhibit ATP dependent electrogenic proton transport with substrate and inhibitor specificities like the membrane bound ATPase. The development of a pH-gradient is prevented and an already existing pH-gradient is dissipated by KCl. On the other hand, KCl has no influence on the generation of the membrane potential. The results suggest that the active component of cation transport is an ATP dependent electrogenic proton pump which energizes proton/cation antiport.

HYPEROSMOTIC URINE SECRETION IN THE RECTA OF SALINE-WATER MOSQUITOES. T. J. Bradley, Dept. of Developmental & Cell Biol., Univ. of California, Irvine, CA, 92717, USA.

The larvae of saline-water mosquitoes are among the most saline tolerant of all aquatic insects. Their capacity to survive in hypersaline media is associated with the secretion of a hyperosmotic urine in the rectum. Na^+ , Mg^{++} , K^+ , and Cl^- are all actively transported from the hemolymph into the rectal lumen. The ratio of ions in the secretion can vary depending on the medium to which the larvae are acclimated. The majority of the hyperosmotic secretion occurs in the posterior rectal segment. In larvae reared in bicarbonate-rich media, modification of the fluid in the rectal lumen occurs by means of Cl^-/HCO_3^- exchange. The exchange, which serves in pH regulation and the retention of Cl^- which would otherwise be lost to the medium, is found in the anterior rectal segment. The interactions of these two rectal segments permit the larvae to survive in saline media of highly variable ionic composition. (Supported by NSF grant DCB 8608664)

THE ARGININE VASOPRESSIN-LIKE DIURETIC HORMONE OF A LOCUST: *LOCUSTA MIGRATORIA*. J. Proux*, A. Girardie, M. Picquot, J.-P. Herault, M. Delaage, C. Miller+ and D. Schooley+. Laboratoire de Neuroendocrinologie, UA CNRS 1138, Université de Bordeaux I, France; & : Société Immunotech, France; +: Zeecon Corp. USA.

Suboesophageal ganglion of *Locusta migratoria* synthesizes an insect neuropeptide structurally related to arginine vasopressin (AVP) the antidiuretic hormone of most mammals. This neuropeptide functions as a diuretic hormone by increasing the excretion of primary urine from the Malpighian tubules. Its release into the haemolymph is under antagonistic control of two neuroendocrine centers located in the brain (median and sub-ocellar neurosecretory cells).

Two AVP-like factors were isolated from a 100,000 ganglia stock, mostly by HPLC techniques, then characterized and synthesized. The more abundant, F1, has sequence Cys-Leu-Ile-Thr-Asn-Cys-Pro-Arg-Gly but its biological role is still unknown. The less abundant, F2, is an antiparallel dimer of F1 and is a diuretic hormone of this species.

F2 acts through the intermediacy of cyclic AMP and is likely degraded by enzymes from the Malpighian tubules. Changes in the haemolymph titre of AVP-like factors and the rate of secretion of primary urine were studied simultaneously for 24 h. Some correlations appear between these two components of water balance.

The evolutionary aspect of the AVP-family are discussed since AVP-related substances have been reported in species as primitive as Hydra.

STRUCTURAL IDENTIFICATION OF AN ARGININE VASOPRESSIN-LIKE DIURETIC HORMONE FROM *LOCUSTA MIGRATORIA*. J. P. Proux¹, C. A. Miller², J. P. Li², R. L. Carney², and D. A. Schooley², ¹UA CNRS 1138, Université de Bordeaux I, 33405 Talence Cedex, France; ²Sandoz Crop Protection, Zeecon Research Institute, Palo Alto, CA 94303, USA.

Two neuropeptides (F1 and F2) which cross-reacted with an arginine vasopressin antibody were isolated from *Locusta migratoria*. Amino acid analysis and sequence analysis of the peptides indicated an identical primary sequence of Cys-Leu-Ile-Thr-Asn-Cys-Pro-Arg-Gly-NH₂. Size exclusion chromatography showed M_r of 700 and 1470 for F1 and F2 respectively, suggesting that F2 could be a dimer of F1. We will discuss the structural proof of F2, the less abundant component which possesses all of the diuretic activity. A nonspecific synthesis gave a mixture containing the two possible dimers. Cleavage of the purified dimers with thermolysin and analysis of the fragments suggested that F2 was the antiparallel dimer. Specific chemical syntheses of both the parallel and antiparallel dimers established unambiguously that this diuretic hormone is an antiparallel dimer. Only two other examples of dimeric neuropeptides are known.

STORAGE AND RELEASE OF DIURETIC HORMONES IN *ACHETA DOMESTICUS*. G.M. Coast, Department of Biology, Birkbeck College, University of London, Malet Street, London, WC1E 7HX, UK.

Diuretic hormones are of widespread occurrence in insects, and diuretic activity has been demonstrated in extracts of brain, retrocerebral complex, and ganglia of the CNS. However, diuretic factors may not be released into the circulation from all of these sites in response to physiological stimuli. This problem has been addressed in the house cricket, *Acheta domesticus*. Fluid secretion by single Malpighian tubules isolated from the cricket is stimulated by aqueous extracts of the brain, corpora cardiaca, corpora allata, and by ganglia of the ventral nerve cord. Diuretic activity from these sites has been quantified, and the release of material in response to K⁺-depolarisation and electrical stimulation has been investigated.

ISOLATION AND CHARACTERISATION OF A DIURETIC HORMONE FROM *ACHETA DOMESTICUS*. G.M. Coast*, C.H. Wheeler, N.F. Totty*, R.J. Philp+ and G.J. Goldsworthy, Department of Biology, Birkbeck College, University of London, Malet Street, London, WC1E 7HX, UK, and +Ludwig Institute for Cancer Research, The Courtauld Building, Rydginghouse Street, London, WC1, UK.

Fluid secretion by the Malpighian tubules of the cricket, *Acheta domesticus*, is stimulated by peptidergic material from the corpora cardiaca (CC). Using reversed phase HPLC two diuretic peptides (DP-1 and DP-2) have been isolated and purified from aqueous CC extracts. DP-2 is the most abundant and stimulates tubule secretion to about 75% of the maximum obtainable with aqueous extracts of freshly dissected glands. Amino acid analysis of acid hydrolysates of this peptide have confirmed its purity. Fast atom bombardment (FAB) mass spectrometry has been employed to determine the molecular weight of the peptide and sequence analysis has been performed using a gas-phase sequencer.

DIURESIS IN CRICKETS: THE DIFFERENTIAL CONTROL OF SECRETION AND REABSORPTION BY HORMONES FROM THE CORPUS CARDIACUM. J.H. Spring*, S.R. Hazelton, and S.A. Alharthy, Biology, Univ. of Southwestern Louisiana, Lafayette, LA 70504, USA.

In *Acheta domesticus*, the formation of primary urine by the Malpighian tubules is under the control of hormones from the corpus cardiacum (CC). The effect of crude CC homogenates was always stimulatory (i.e. diuretic) and the maximum response was a doubling of the rate of urine formation. The response was rapid and short-lived, with the maximum secretory rate being achieved in 15-30 min, and the rate dropping precipitously after 60 min of stimulation. Analysis of the urine indicated that the potassium content increased by only 50% whereas the sodium increased 5-fold. Liquid chromatography (HPLC) of CC extracts revealed 4 active peaks - 3 stimulatory (diuretic) and 1 inhibitory (antidiuretic). In contrast to their action on the tubules, CC homogenates always caused the rectum to reabsorb fluid (i.e. antidiuretic) and the reabsorption rate increased by 5-fold. Response time to stimulation was significantly slower and more prolonged than in the tubules. At least 90 min was required to reach the maximum resorption rate which then remained elevated for more than 3 h. In stimulated preparations, sodium was preferentially reabsorbed. It has not been determined which CC fractions affect the rectum.

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PROGRESS TOWARD THE ISOLATION OF THE MOSQUITO NATRIURETIC HORMONE AND OTHER EXCRETORY FACTORS FROM *Aedes Aegypti*. T.K. Hayes* and K.W. Beyenbach, Department of Entomology, Texas Agricultural Experiment Station, Texas A&M University, College Station, TX 77843; Section of Physiology, Division of Biological Sciences, Cornell University, Ithaca, NY 14853.

Several natriuretic and excretory factors have been extracted from whole heads of *Aedes aegypti* for isolation and sequence analysis. Each factor was identified by effects on the transepithelial voltage (V_t) of isolated-perfused Malpighian tubules from the same mosquito species. Ice-cold trifluoroacetic acid (TFA, 15%, v/v) was used to extract the factors from whole heads and partially deproteinize the initial peptide solution. RP-HPLC resolves the activity into three major fractions. Fraction I and II depolarize the V_t, while Fraction III also causes hyperpolarization. Fractions II and III can be selectively removed from the RP-HPLC extract by propylglycol bonded phase HPLC. Final purification and desalting of these active fractions is accomplished by additional RP-HPLC. Amino acid analysis agrees with previously reported molecular weight estimates for these factors.

Structure-activity studies for a recently characterized family of insect neuropeptides will be introduced. Several of these peptides show pronounced effects on mosquito Malpighian tubule fluid secretion. These results could help identify active pharmacophores related to those found in the excretory factors from *Aedes aegypti*.

FUNCTIONAL AND IMMUNOLOGICAL SIMILARITIES BETWEEN VERTEBRATE ACTH AND LOCUST DH. A. Rafaeli*, Department of Entomology, Faculty of Agriculture, Rehovot 76100, Israel.

Synthetic vertebrate adrenocorticotrophic hormone (ACTH) has been shown to mimic the physiological and cellular response of the locust diuretic hormone (DH). The physiological response was expressed as a dose-dependent increase in fluid secretion by *in vitro* Malpighian tubules, similar to that of DH. The cellular response was expressed as an increase in the secretion of cAMP by *in vitro* Malpighian tubules, significantly different from basal cAMP secretory levels. Immunological similarities between ACTH and DH were evident when crude corpora cardiaca (CC) methanolic extracts containing DH reacted positively with a sensitive and specific ACTH radioimmunoassay. An HPLC separation of methanolic extracts of CC was performed where fractions tested in parallel for the DH response and for an ACTH immunoreactive response resulted in two DH responses both of which coincided with a positive ACTH immunoreactive response. An HPLC separation of synthetic ACTH showed a different retention time indicating that DH and ACTH are not identical peptides.

STIMULATION OF ELECTROGENIC ION TRANSPORT IN SCHISTOCERCA ILEUM BY FACTORS FROM CORPUS CARDIACUM AND VENTRAL ABDOMINAL GANGLIA. N. Audsley and J.E. Phillips, Department of Zoology, U.B.C., Vancouver, B.C., Canada V6T 2A9

We have studied ion transport mechanisms and their control for the first time in insect ileum, using epithelia mounted as flat sheets in Ussing chambers and bathed in saline resembling hemolymph. Short-circuit current (I_{sc}) and transepithelial potential (V_t), both indicating net anion absorption, declined rapidly to near zero after 2 h. Both I_{sc} and V_t were fully restored by addition of either cAMP or forskolin to the hemocoel side. Ion substitutions and Cl-fluxes indicated that increase in I_{sc} was due to active transport of Cl^- (J_{Cl}), as previously observed for rectum. However, cAMP also (1) stimulated active absorption of $^{22}Na^+$ (J_{Na}) in the ileum, (2) dramatically altered the transport of acid-base equivalents, and (3) increased potassium permeability and conductance (G_t). The locust neuroendocrine system was surveyed for factors which mimic these actions of cAMP on ileum. Ventral abdominal ganglia (VG) and corpus cardiacum (CC) both stimulated I_{sc} , V_t and G_t in a dose-dependent manner, and this activity was destroyed by chymotrypsin and by boiling. However, very different time courses of the I_{sc} response suggest that the CC and VG factors are different neuropeptides.

STIMULANTS OF ILEAL FLUID ABSORPTION IN SCHISTOCERCA GREGARIA. J.E. Phillips and R. Lechleitner, Department of Zoology, U.B.C., Vancouver, B.C., Canada V6T 2A9

Using locust ilea mounted in Ussing chambers, we recently demonstrated that rates, properties and control of salt absorption in locust ileum are similar to those previously demonstrated for the rectum. Since fluid absorption (J_v) in the absence of transepithelial osmotic concentration differences ($\Delta osmol$) is normally driven by active transport of ions, we used everted ileal sacs from locusts to demonstrate that agents which stimulate salt transport also increase J_v by up to 5-fold in a dose-dependent manner: i.e. cAMP, both nervous and glandular lobes of corpus cardiacum (CC), and 5th ventral ganglion (VG). These stimulants also increased the maximum $\Delta osmol$ against which J_v occurred from 600 to >750 mosmol. Changes in the $J_v/\Delta osmol$ relationship indicated increases in both the active component of J_v and in osmotic permeability of the ileum. The ileal absorbate remained slightly hyperosmotic to the luminal saline, whereas rectal absorbate was 25% hypoosmotic. We also report on the influence of stimulants and varying luminal ion ratios on J_v rate and absorbate ionic composition. Overall our results are consistent with the hypothesis that the same CC and VG stimulants act on NaCl and KCl transport to increase J_v in both locust ileum and rectum.

ANTIIDIURETIC HORMONES OF LOCUSTA MIGRATORIA STIMULATING RECTAL FLUID REABSORPTION. J. Proulx*, J.-P. Herault, B. Fournier, D. Bourême and J. Girardie. Laboratoire de Neuroendocrinologie, UA CNRS 1138, Université de Bordeaux I, France.

Corpora cardiaca (CC) of the migratory locust contain two antidiuretic (AD) factors increasing the fluid reabsorption of isolated recta over a 5-h period. The used assay was progressively improved to save time and biological material. Our latest experiments were carried out within 2 hours instead of 5 hours at the beginning. These two AD factors are contained in storage lobes (SL) and glandular lobes (GL) of the CC respectively. They were separated using several proper separation procedures.

The AD factor contained in the SL of the CC is the "neuroparsin". It is a very stable protein isolated to apparent homogeneity and whose sequence is in progress. It enhances fluid reabsorption at the rectal level via second messengers other than cyclic AMP.

The AD factor contained in the GL of the CC is an unstable peptide. It acts via cyclic AMP and its release into the haemolymph seems to be controlled by octopamine, which is probably synthesized in the lateral neurosecretory area of the brain.

Similar substances are present in the SL and GL of the CC of two cockroaches. Locust AD substances act on the cockroach recta and conversely.

STIMULATION OF SALT AND WATER TRANSPORT IN MALPIGHIAN TUBULES OF FORMICA. E. Van Kerkhove*, N. De Decker and R. Weltens, L.U.C., Universitaire Campus, B-3610 Diepenbeek, Belgium.

Malpighian tubules of *Formica* were isolated and secreted fluid was collected. The mean fluid secretion rate in control Ringer (51 mM K & 57 mM Cl) was 230 pl/min $\pm$ 13 SE (119 tubules). The range of values was very wide: throughout the year ants were found with inactive tubules and others with tubules secreting at various rates (8 - 800 pl/min). This could be due to the presence of different levels of a hormonally regulated active state in the tubules. In an attempt to find out what factors might be involved in the regulation in *Formica* species, the effect of 5-HT and different forms of cAMP was studied. 10^{-5} to 10^{-3} M 5-HT did not change the fluid secretion rate. db-cAMP (10^{-3} M) and 8-bromo-cAMP (10^{-3} M) accelerated it with a factor of 1.6. CPT-cAMP (10^{-6} or 10^{-5} M) caused a higher increase (x 2.5). CPT-cAMP, however, had no effect on the basolateral membrane potential. Neither had replacement of Cl^- with NO_3^- or SO_4^{2-} or application of bumetanide (10^{-3} M) although fluid secretion fell to a very low level. These data suggest that, as in other insect species, hormonal factors acting via cAMP may be present in the haemolymph of *Formica*. cAMP might exert part of its effect by stimulating an electrically silent cation-anion co-transporter present in the basolateral membrane.

INSECT HYPERTREHALOSEMIC HORMONE STRUCTURE-ACTIVITY STUDIES: IDENTIFICATION OF CORE RESIDUES AND POTENTIAL CONFORMATIONS. T.K. Hayes, Department of Entomology, Texas Agricultural Experiment Station, Texas A&M University, College Station, TX 77843

Blaberus discoidalis hypertrehalosemic hormone (HTH, pGlu-Val-Asn-Phe-Ser-Pro-Gly-Trp-Gly-Thr-NH₂) is a member of the AKH/RPCH hormone family. The hormone elevates hemolymph trehalose concentrations as much as 3.5x higher than resting levels following injection in this insect. Several analogs were prepared by solid phase peptide synthesis for biological evaluation.

The first study compared the activities of the first nine natural analogs of HTH found in other insect and Crustacean species. HTH was the most active peptide when *B. discoidalis* is used as the test species. HTH was 10x more potent than the next most active natural analog, Periplanetin CC1. *Manduca/Heliothis* AKH has no activity and differs from HTH at six out of the ten residue positions. The closer the sequence homology to HTH the greater the potency of the natural analog.

The second set of analogs was designed to have one replacement amino acid for each analog to test the importance of each side chain and termini of HTH for biological activity. The results of these studies suggest that 1) pGlu, Phe and Trp are critical for receptor binding; 2) the C-terminal amide or lack of charge on the peptide is important for transduction of biological activity; and 3) that the hormone may be recognized in a folded conformation induced by the presence of a turn at residues 5-8.

THE HYPERTREHALOSAEMIC HORMONES OF COCKROACHES - A PHYLOGENETIC STUDY. G. Gäde, Institut für Zoologie IV, Universität Düsseldorf, D-4000 Düsseldorf 1, Fed. Rep. of Germany.

The corpora cardiaca of cockroaches contain peptides that are involved in carbohydrate release via activation of fat body glycogen phosphorylase and breakdown of glycogen and are collectively known as hypertrehalosaemic hormones. We studied the chromatographic profile (by means of reversed-phase high performance liquid chromatography) and biological activity (by a bioassay) of corpus cardiacum material from 12 different cockroach species belonging to the three different families: the Blattidae, Blaberidae and Blattellidae. All of the five species of the family Blattidae (*Periplaneta americana*, *P. fuliginosa*, *P. brunnea*, *P. australasiae*, *Blatta orientalis*) had the octapeptide MI and some of them also the octapeptide MII as their hypertrehalosaemic hormones. All six members of the family Blaberidae (*Nauphoeta cinerea*, *Blaberus trapezoides*, *B. craniifer*, *B. discoidalis*, *Leucophaea maderae*, *Gromphadorrhina portentosa*) had at least one peptide, the decapeptide HTH, as hypertrehalosaemic hormone. The only species from the family Blattellidae investigated, *Blattella germanica*, contained also the decapeptide HTH in its corpus cardiacum.

STRUCTURE/ACTIVITY RELATIONSHIPS IN THE AKH FAMILY

G.J. Goldsworthy*, C.H. Wheeler, A.F. Drake, C. Wilmot and G. Gäde*, Birkbeck College, University of London, Malet Street, London, WC1E 7HX, UK, and *Zoological Institute, University of Dusseldorf, D-4000 FRG.

Individual locusts possess two peptides of the AKH family of hormones: either one, depending upon species, of the octapeptides AKH-IIL or AKH-IIS, and AKH-I. Circumstantial evidence suggests that they have different receptors. For biological activity, peptides of this family must be blocked; the peptides must be 8-10 amino acids long; and substitutions around residues 6 to 8, which are assumed to interfere with a β -turn (in those with proline at 6), reduce biological activity. By CD spectroscopy we can show that AKH-I, RPCH, MI and MII adopt a characteristic type-I β -turn when binding to SDS-micelles. Neither of the locust octapeptides show such conformations. We are now modelling these peptides and looking at their secondary structures using NMR spectroscopy.

DISTRIBUTION OF AKH AND ITS HOMOLOGY WITH OTHER NEUROPEPTIDES. S.W. Applebaum* and P. Moshitzky. Department of Entomology, The Hebrew University, Rehovot 76-100, Israel.

AKH-like immunoreactive material is widely distributed in the nervous system of insects. The synthesis of locust AKH-I *de novo* in the brain and corpora cardiaca has been established by HPLC, bioassay, sequence analysis and incorporation of tritiated tryptophan. The temporal distribution of AKH-I during the reproductive cycle of female locusts was next examined by RIA. AKH first appears in the hemolymph at 3mm oocyte length (≤ 0.25 ng/ml hemolymph), and peaks at 6mm (5-10 ng/ml). Inhibition of fat body protein synthesis, and specifically vitellogenin (VG) synthesis by hemolymph extracts, parallels the increase in HPLC-isolated AKH and of AKH as determined by RIA. Inhibition is mediated by cAMP in a dose-dependent manner. Female fat body competence to respond to AKH increases as oocytes mature. Brain levels of AKH are high in previtellogenic females (10-40 ng/brain) and at 6mm oocyte length (≈ 40 ng/brain), and only ≈ 0.5 ng/brain during active VG synthesis. The role of AKH in control of VG synthesis is discussed. Functional and sequence homology in the AKH family, and to known vertebrate proteins, is critically examined.

REGULATION OF ENERGY METABOLISM IN LOCUST FLIGHT.

G.Wegener*, I.Beinhauer, C.Blau and A.A.G.Thomas, Institut für Zoologie, Johannes Gutenberg-Universität, D-6500 Mainz, FRG, and Department of Biochemistry, Oxford University, Oxford OX1 3QU, U.K.

At the initiation of flight the glycolytic rate in flight muscle is rapidly increased. Using the non-invasive ^{31} P phosphorus magnetic resonance spectroscopy we have shown that flight causes little change in the content of ATP in flight muscle of *Locusta migratoria*, but brings about a decrease in the content of phosphoarginine and an increase in inorganic phosphate (P_i). P_i can activate various enzymes of carbohydrate catabolism, especially the glycolytic key enzyme phosphofructokinase (PFK, EC 2.7.1.11). Glycolysis in flight muscle is probably also activated by the nervous system through octopamine. Octopamine, injected into resting locusts, caused a highly significant increase in the content of fructose 2,6-bisphosphate ($F_{2,6}P_2$), a most potent activator of PFK from flight muscle.

In sustained flight, fat replaces carbohydrate as the major fuel, and carbohydrate is spared. This is, in part, brought about by inhibition of PFK through a marked decrease in the content of $F_{2,6}P_2$ in flight muscle during the first 15 min of flight.

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ISOLATION AND CHARACTERISATION OF MYOACTIVE PEPTIDES FROM *ACHETA DOMESTICUS*.

C.H. Wheeler*, G.M. Coast, N.F. Totty*, R.J. Philp* and G.J. Goldsworthy, Department of Biology, Birkbeck College, University of London, Malet Street, London, WC1E 7HX, UK, and *Ludwig Institute for Cancer Research, The Courtauld Building, Rydginghouse Street, London, WC1, UK.

Malpighian tubules from Orthopteroid insects are spontaneously contractile but the rate of contraction is dependent on the physiological state of the insect. In *Acheta*, Malpighian tubules from starved animals contract much more vigorously than those from fed insects. The tubules from starved insects are often filled with uric acid crystals and such contractions may facilitate their expulsion. The contraction of the tubules must be under the control of hormones since there is no innervation of the tubules themselves. We have isolated and characterised two neuropeptides from the corpora cardiaca of house crickets which affect Malpighian tubule contraction. The assay and characterisation of these factors will be discussed.

ISOLATION AND STRUCTURE ELUCIDATION OF AN ALLATOTROPIN FROM ADULT *MANDUCA SEXTA* AND ITS EFFECTS ON CORPUS ALLATUM ACTIVITY *IN VITRO*. H. Kataoka, A. Toschi, S.J. Kramer* and D.A. Schooley, Sandoz Crop Protection, Zeecon Research Institute, Palo Alto, CA 94304

A peptide which stimulates the secretion of juvenile hormones from corpora allata *in vitro* (allatotropin) has been purified from head extracts of pharate adult *M. sexta*. Allatotropin activity was limited to the adult stage of *M. sexta*. The primary structure of allatotropin has been determined and consists of 13 amino acids. This neurohormone appears to have no sequence similarity with any known neuropeptide from other organisms. Native and synthetic allatotropin displayed identical chromatographic behavior and *in vitro* biological activity. Species specificity studies revealed *in vitro* activity in only adult lepidopteran species.



INNERVATION AND CONTROL OF VISCERAL MUSCLES: THE INNERVATION OF THE OVIDUCT AS A PRIME EXAMPLE. I. Orchard* and A.B. Lange, Department of Zoology, University of Toronto, Toronto, Ontario, M5S 1A1

The neurons that supply internal organs may be considered to constitute the autonomic nervous system, with the meaning that they function as an independent 'autonomous' system with a self-contained hierarchy of functional units and internal state generators (Shepherd, "Neurobiology", Oxford University Press). In insects the autonomic or visceral nervous system has generally been described as consisting of a) the stomatogastric system, b) the unpaired ventral nerves and c) the caudal sympathetic system associated with the terminal ganglion of the abdomen (Wigglesworth, "Principles of Insect Physiology, Chapman and Hill). However, an indication that the system is more extensive than this is revealed by the description of internal organs innervated from the nervous system outside of these three areas. For example, locust oviducts receive innervation from the penultimate abdominal ganglion, and salivary glands from the sub-oesophageal ganglion.

This review will introduce the concept of an autonomic nervous system in insects and examine the characteristics of its control over a visceral muscle, namely locust oviduct. It will be shown that this visceral muscle receives both peptidergic and aminergic innervation as well as being under neurohormonal influence.

THE STOMATOGASTRIC NERVOUS SYSTEM (SGNS) IN INSECTS. Norman T. Davis, Department of Physiology and Neurobiology, University of Connecticut, Storrs, CT USA 06268

The SGNS controls the release of digestive secretions and the movements of the fore- and mid-gut. There is a need for more study of its physiology. It consists of the frontal connectives, frontal ganglion, and a median nerve leading to smaller ganglia and to branches innervating the salivary gland and muscles of the fore- and mid-gut. The system also has nerves coming from the retrocerebral complex, subesophageal ganglion, and tritocerebral commissure. Some of its neurons have been mapped. In the cockroach the system may be augmented by a diffuse proctolin-serotonin neurohemal system. The SGNS may control salivary secretion by dopamine and 5-HT stimulation. Visceral muscles may be controlled by stimulation by proctolin and relaxation by amines. A FMRFamide-like substance may also be released.

Mid-gut secretion appears to be controlled by a variety of neuroendocrine cells that may produce FMRFamide-like and proctolin-like peptides as well as several peptides resembling those of the vertebrate gastroenteric tract.

HORMONAL CONTROL OF INSECT HEARTBEAT. T. Miller, Entomology Department, University of California, Riverside, CA 92521, USA.

Control of insect heartbeat has been demonstrated in two cases. Heinrich showed that nervous control of heartbeat and ventral diaphragm in some Hymenoptera and Lepidoptera was important in control of thoracic temperature by controlling removal of warm hemolymph from the thorax. Tublitz showed release of a cardioacceleratory factor from the median nervous system that acted on the dorsal vessel of *Manduca sexta* to modify the heartbeat during wing expansion of the newly emerged adult. Although many possible control mechanisms abound in the dorsal vessel of insects, the latter remains the only clear demonstration of a hormonal control of insect heartbeat.

THE PERISYMPATHETIC SYSTEM IN INSECTS: STRUCTURE AND DEVELOPMENT. P. Taghert (USA).

No Abstract

AUTONOMIC NERVOUS SYSTEM IN INSECT RESPIRATION.

K. Sláma, Insect Chemical Ecology Unit, UOCHB, Czechoslovak Academy of Sciences, 15800 Praha 5, Czechoslovakia.

The newly developed thermographic, tensiometric and respirographic methods revealed active regulation of inspirations through one or two spiracles while the rest remained hermetically closed. During the rhythmic pulsations in hemocoelic pressure, some spiracles opened and closed at different locations so that CO₂ was quickly ventilated. In the prolonged periods of sub-atmospheric hemocoelic pressure, the spiracles usually opened in "twinkles" lasting only 50 to 300 msec. It is concluded that insect respiration is controlled by a hitherto unknown, brain independent or autonomic mechanism consisting of two main components: a) a mechanism that integrates proprioceptive input to control the location and timing of the spiracular openings, and b) a coordinated system of hemocoelic pressure control that regulates the force and direction of air flow through the spiracles.

RELATIONSHIP BETWEEN INSECT CIRCULATION AND RESPIRATION

L.T. Wasserthal, Zoological Inst. 1, Staudtstr. 5, 8520 Erlangen, FRG.

In resting adult holometabolous insects, hemolymph oscillates between anterior body and abdomen by periodic heartbeat reversal or heart pauses and discontinuous flow through the perineural sinus. The periodic changes in hemolymph volume induce changes in volume of the tracheal air sacs of the anterior body. This is facilitated by the extensibility of the tracheal intima and the tracheal cytoskeleton. Periodic tracheal extension is documented by combining contact thermography with scanning electron microscopy of shock-frozen specimens at specified moments or with time lapse micrography of "sleeping" insects.

The abdominal air sacs may be ventilated by oscillating hemolymph alone or by abdominal ventilatory bursts, which in some insects are coordinated with heartbeat periods. In a desert carabid beetle, running activity is obviously initiated during the ventilatory bursts which coincide only with forward pulse periods of the heart.

THE AUTONOMIC NERVOUS SYSTEM IN INSECTS. M. O'Shea (Switzerland).

No Abstract

MOLECULAR ISOLATION AND ANALYSIS OF A PUTATIVE PHOSPHOLIPASE C GENE EXPRESSED IN THE DROSOPHILA EYE. R. Shortridge*, B. Bloomquist, S. Schneuwly, M. Perdew, and W.L. Pak, Department of Biological Sciences, Purdue University, West Lafayette, Indiana, 47907.

Severe *norpA* mutations in *Drosophila* eliminate the responses of the photoreceptor. Evidence suggests the *norpA* gene encodes a protein directly involved in an intermediate step of phototransduction. Inoue et al. (1985) reported that *norpA* mutations affect the phospholipase C activity in the eye. We obtained from H. Steller, C. Montell and G. Rubin, two cosmids containing DNA from the region between the distal breakpoints of two gamma-ray induced deficiencies, *Df(1)rb41* and *Df(1)bid2*, which define the location of the *norpA* gene. Although the distal breakpoints of these deficiencies are cytologically indistinguishable, *rb41* deletes the *norpA* function, while *bid2* leaves it intact. We have also isolated a *norpA* allele in P-M hybrid dysgenesis experiments which contains a hobo element within the same region as that cloned into the cosmids. Northern hybridizations using genomic DNA from this region show that the putative *norpA* transcript is approximately 7-kb in length and expressed only in the head of adult flies. We have shown that a cDNA that corresponds to this region hybridizes to the photoreceptor in tissue sections taken from the adult fly head. DNA sequence analysis of the genomic region, and of cDNAs we have isolated, is in progress.

NATURAL AND GENETICALLY ENGINEERED VISUAL PIGMENTS IN THE FLY. K. Kirschfeld, Max-Planck-Institut für biologische Kybernetik, Spemannstrasse 38, D-7400 Tübingen, FRG.

Seven different visual pigments have been demonstrated in photoreceptors of the compound eye of *Musca*. Similar pigments are also present in other fly species like *Calliphora* and *Drosophila*. Typical for several of these pigments is the presence of a second chromophore which acts as a "sensitizing pigment".

By molecular genetic techniques C. Zuker¹ linked the promoter of the gene that encodes the visual pigment in the cells R1 to 6 to a gene that encodes one of the other visual pigments (called Rh 2) in *Drosophila*. If this in vitro construct is transformed into the genome of mutant flies that lack the visual pigment in receptors R1 to 6, these flies express a visual pigment in these receptors. We investigated the visual system of these flies by means of microspectrophotometry, electrophysiology and in behaviour: they can "see" again, but with a modified spectral sensitivity. This spectral sensitivity corresponds to that of the ocelli, therefore Rh2 may be the ocellar visual pigment.

Ref.: R. Feiler, W. Harris, K. Kirschfeld, C. Wehrhahn, C. Zuker, in prep.

¹Department of Biology, University of California, San Diego, La Jolla, California.

MECHANISMS OF ADAPTATION IN BLOWFLY PHOTORECEPTORS.

K. Hamdorf and P. Hochstrate, Inst. Zoophysiology, Ruhr-University, 4630 Bochum 1, F.R.G. The receptors R1-R6 of blowfly are known to adapt their sensitivity very fast over a wide range of light intensity. Based on quantitative experiments, three intensity ranges of different adapting properties can be distinguished: 1) a range of low adapting intensities (up to 600 absorbed quanta per s and receptor) in which the amplitude of the response to test stimuli remains constant, but latency, peak time and duration of the response become shortened; 2) a wide range of more than 3 log intensity units in which the amplitude/log I-functions are continuously shifted towards higher intensities; 3) a range of bright light in which the receptor becomes dazzled. Such conditions are given when fly's ommatidia are looking straight into the sun. The mechanisms responsible for the three adaptation effects are basically different. The 1st phenomenon is most probably caused by local desensitization of small membrane areas. The 2nd phenomenon is strongly correlated with the increase of free Ca^{++} which desensitizes the light sensitive channels, and the 3rd phenomenon is caused by a period of blockage of the biochemical amplification.

This work was supported by the Deutsche Forschungsgemeinschaft through Konzell.

RHABDOMERE AUTOPHAGY AND RHODOPSIN CYCLE IN *Drosophila* W. S. Stark*, R. Sapp and D. Schilly, Div. Biol. Sci. Univ. of Missouri, Columbia, MO 65211 USA.

Turnover of visual pigment and membranes was studied in *Drosophila*. Microspectrophotometry (MSP) of deep pseudopupils in white eyes revealed R1-6's visual pigment on a 12:12 hr light cycle (50 cd/m² fluorescent light). Absorbance difference at metarhodopsin's 579 nm maximum was determined after 450 vs 620 nm photoequilibria maximized metarhodopsin vs rhodopsin respectively (cf. Stark & Johnson J.Comp.Physiol.140 275-286,1980). Photopigment decreases by half 3 hr after dawn, building up by the next dawn. Diurnal rhythms had not been noted in the fly but had in other invertebrates. EM fixations were several hours after dawn when autophagy may be high if visual pigment and membrane levels covary. Coated pits pinch off from microvilli and plasmalemma. Multivesicular bodies (MVB's) 0.5 µm dia. are seen merging with up to 10 spheres of 0.15 µm, likely primary lysosomes. Histochemistry for the lysosomal enzyme acid phosphatase shows punctate densification, suggesting a positive reaction, in dense but not loose MVB's, Golgi cisterns and lysosomes. No staining is in controls (Acph-, lacking Acid phosphatase). Rhabdomere building was viewed during carotenoid replacement which increases visual pigment; membranes near rhabdomeres may carry opsin to microvilli.

TEMPERATURE DEPENDENT MEMBRANE PROCESSES OF FLY PHOTORECEPTOR CELLS: EARLY AND LATE RECEPTOR POTENTIAL MEASUREMENTS.

J.G.H. Roebroek* and D.G. Stavenga, Biophysics, State University, Westersingel 34, Groningen, the Netherlands.

The visual pigment of blowfly photoreceptor cells R1-6 is a blue-green absorbing xanthopsin P490, which upon light absorption converts via two thermolabile intermediates into a thermostable orange absorbing meta-state M580. M580 is photoconverted back into the native P490 via an intermediate K and a newly characterized intermediate N, which decays with a time constant of 13 ms at room temperature.

Early receptor potential (ERP) measurement of the M → P transition yields a biphasic depolarisation of the receptor membrane. The time course of the second hyperpolarising phase of the ERP is closely related to that of the last photochemical transition: N → P.

Intracellular recordings from photoreceptor cells were performed at various temperatures (10 - 30°C). The amplitude of the late receptor potential (LRP) is virtually independent of the temperature, but the time course is strongly temperature dependent: Q₁₀ = 2.5.

These results will be discussed in relation with ERP and LRP measurements of invertebrate photoreceptors in general.

SYNAPTIC ORGANISATION OF THE LAMINA CARTRIDGE IN *DROSOPHILA*. I.A. Meinertzhagen* and S.D. O'Neil, Life Sciences Centre, Dalhousie University, Halifax, Nova Scotia, Canada B3H 4J1.

The visual system in *Drosophila* is understood in many details but the anatomy and electrophysiology of the adult optic lobe have been little studied. The synaptic organisation of the first optic neuropile, or lamina, has been particularly neglected. We have examined the synaptic connections of cells in the lamina cartridge of *Drosophila* from a series of 600 consecutive transverse EM sections.

The cellular organisation is the same as in *Musca* but less orderly. Selective examples of synaptic connections amongst receptor (R1-6) and monopolar (L1-L5) cells, other narrow-field elements (C2 & C3, centrifugal, and T1, basket cells), and amacrine cell (α) processes that pair with those (β) of T1, differ from their counterparts in *Musca* as follows: L3 contributes at R1-6 afferent tetrads in the proximal lamina; L2 forms feedback synapses upon R1-6 but with L4, not T1, the second element of a postsynaptic dyad; L3 receives α input along with β at dyads; L5 receives rare input from C2; T1 receives α input at so-called gnarls but there are no reciprocal T1 inputs upon α; α processes form a second feedback upon R1-6, as in *Lucilia*. Our observations on the wild type provide the first basis for the analysis of *Drosophila* connectivity mutants which should reveal the nature of the genetic control of synaptic selectivity.

Supported by grants A 0065 (NSERC) and EY03592 (NIH).

SPATIAL AND TEMPORAL PROCESSING IN THE FLY LAMINA. Hans van Hateren, Department of Biophysics, University of Groningen, Westersingel 34, NL-9718 CM Groningen, The Netherlands.

Antidromic light, i.e. light travelling in the reverse direction through the retina, is used for visualization of the photoreceptors in the eye of the blowfly *Calliphora erythrocephala*. This enables precise stimulation of individual photoreceptors^{1,2}. Intracellular recordings from photoreceptor cells and LMCs (Large Monopolar Cells, second order neurons in the fly lamina) show that photoreceptors looking into the same direction are electrically coupled, and superimpose their signals onto the LMCs (neural superposition³).

Abrupt changes in illumination of photoreceptors elicit oscillations in the LMC membrane potential of approximately 180 Hz. These oscillations are more pronounced when illuminating single photoreceptors than when illuminating all photoreceptors participating in the neural superposition at the same time. It is shown that increasing the stimulus size again enlarges the oscillations, indicating that lateral interactions are involved. A similar behaviour is found in field potentials in higher optic lobes, and in the spike rate of movement sensitive neurons situated in the lobula plate.

1 Hateren JH van (1986) J Comp Physiol A 158:795-811

2 Hateren JH van (1987) J Comp Physiol A 161:849-855

3 Kirschfeld K (1967) Exp Brain Res 3:248-270

FROM THE RETINA TO THE MEDULLA OF THE FLY: ANALYSES OF PERIODIC RESPONSES TO MOVING GRATINGS. R.D. DeVoe*, C. Gilbert, D.K. Penisten, School of Optometry, Indiana University, Bloomington, Indiana 47405, USA

Flicker and moving gratings of equivalent (contrast) frequencies elicit equivalent harmonics in periodic responses of photoreceptor cells (R1-6) and laminar monopolar cells (LMC's) of *Sarcophaga* and *Calliphora*.

Small-field medullary cells with noisy LMC-like responses, or with noisy on-off depolarizations, also have flicker-like periodic responses to moving gratings. These periodic responses may be directionally selective (DS) or orientation selective (OS). Lucifer yellow stained cells (all non-DS) were columnar and projected to the lobula.

Altogether different were larger-field cells with non-DS, sustained depolarizations to movement (flicker always elicited just periodic responses). Superimposed periodic ripple, when present, was sometimes DS or OS. Such responses had ripple and/or increasing depolarizations for movements up to 20-30 Hz contrast frequencies. Stained cells included amacrine, and Y or columnar cells projecting to the lobula and/or lobula plate. These cells are unlikely candidates to be inputs to lobular plate optomotor neurons with 2-5Hz band passes. Supported by NIH grants EY05163 and EY05903.

IDENTIFICATION OF OPTIC LOBE NEURONES OF LOCUSTS USING VIDEO FILMS. M. Gewecke*, K. Kirschfeld and R. Feiler, Zoologisches Institut, Universität Hamburg, and MPI für biologische Kybernetik, Tübingen, Fed. Rep. Germany.

We studied the response characteristics of visual interneurons in *Locusta migratoria* and *Schistocerca gregaria*. Alternating light and dark, flicker, moving dots, bars, and stripes were used for stimulation. Stimuli were recorded with a video system and replayed on a TV-screen to allow fast testing during the limited intracellular recordings. Physiological data were stored and analysed with a computer. Cells were identified by intracellular injections of Lucifer yellow. From the morphological and physiological characteristics several classes of visual interneurons were distinguished in the medulla and lobula: cells responding to light (on), dark (light off), flicker, and moving small dots or bars. One class is direction sensitive and may, therefore, be involved in optomotor flight control.

ORGANIZATION OF VISUAL OUTPUTS FROM THE BRAIN TO THE MOTOR CENTERS OF DIPTERA. Nicholas J. Strausfeld* and Jürgen J. Milde, Arizona Research Laboratories Division of Neurobiology, University of Arizona, Tucson AZ 85721, U.S.A and Zoologisches Institut der Universität zu Köln, D-5000 Köln 41, Weyertal 119, Federal Republic of Germany.

Anatomical and intracellular studies of the dipteran central nervous system demonstrate that outputs from small-field interneurons of the lobula, and wide-field motion sensitive neurons of the lobula plate, converge onto common postsynaptic interganglionic interneurons (descending neurons; DNs) of the deutocerebrum that receive a variety of other sensory inputs. DNs typically respond to context specific visual and multimodal stimuli. DNs are structurally organized as clusters, each member of the cluster responding to similar contextual parameters. Axons of DNs diverge to discrete motoneuron-local interneuron circuits in the thoracic and abdominal ganglia. The anatomical organization of each DN in segmental ganglia suggests that information that is relevant to coordinated motor activity by several segments is relayed to the appropriate neuropils by one or more segmentally branching DN originating from a specific DN cluster. However, the same information is relevant to other motor outputs that contribute to independent behavioral repertoires. Anatomical evidence suggests that the same cluster supplies such circuits by a segregated channel consisting of one or more diverging DNs. Examples are: DNs involved in visually stabilized flight that segmentally innervate neck, flight motor and abdominal neuropils. And, from the same local area of neuropil, DNs that separately invade segmental circuits involved in the control of posture and walking. Supported by NIH Grant No. RO1 EY07151-01

PHYSIOLOGICAL AND HISTOLOGICAL FINDINGS ON EFFERENT FIBER SYSTEMS IN THE EYES OF BEETLES.

Günther Fleissner* and Gerta Fleissner, Zoological Institute, University of Frankfurt/Main, Siesmayerstr.70, D-6000 Frankfurt/Main, FRG.

Insect vision underlies efferent control mechanisms which can set limits to afferent (light-) adaptation.

The authors present histological and physiological data on identified fibersystems in the visual system of beetles, which are involved in these processes. Special interest is laid upon the circadian sensitivity changes.

NEURONAL BASIS OF VISUAL BEHAVIOR IN *MANDUCA SEXTA* (SPHINGIDAE: LEPIDOPTERA). J.J. Milde* and G. Wendler, II. Zoologisches Institut der Universität zu Köln, Weyertal 119, D-5000 Köln, Federal Republic of Germany.

In arthropods a variety of interneurons have been identified which underly optomotor responses. In flies, pathways from optomotor interneurons in the lobula plate to neck muscles have been revealed recently. *Manduca sexta* also has a lobula plate and a variety of large optic lobe interneurons. Rotating periodic gratings elicit strong head movements in flying as well as in resting moths. In a first stage of analysis, a variety of visual interneurons have been characterized physiologically and anatomically. By developing a preparation which allows the comparison of intracellular measured responses of identified visual interneurons with simultaneously recorded neck muscle activity, the role of a particular neuron in generating optomotor responses will be clarified. Furthermore the comparative aspects to the optomotor system of flies result in valuable new insights.

FROM MOTION DETECTION TO VISUAL ORIENTATION: A BEHAVIORAL, NEURONAL, AND THEORETICAL ANALYSIS ON THE VISUAL SYSTEM OF THE FLY. M. Egelhaaf, Max-Planck-Institut für biologische Kybernetik, Spemannstr.38, D-7400 Tübingen, Fed.Rep.Germany.

The spatial distribution of light intensity received by the eyes changes continually when an animal moves around in a contrasted environment. The information inherent in these retinal motion patterns can be used in the control of visual orientation. In a combination of behavioral and electrophysiological analysis as well as by model simulations, the neural mechanisms are established by which the visual system of the fly evaluates two different types of basic retinal motion patterns. Coherent large-field motion as is induced by self-motion of the animal and relative motion between objects and their background are extracted by separate neuronal networks which are specifically tuned with respect to their spatial and temporal properties. One of them ('large-field system') is most sensitive to the motion of large textured patterns and relatively low oscillation frequencies. In contrast, the other ('small-field system') is tuned to the detection of small moving patterns and shows its strongest responses at higher oscillation frequencies. At the neuronal level, the two networks are represented by different functional and anatomical classes of output cells of the optic lobes. This separation into functional pathways is maintained up to the level of the direct flight muscles and is reflected at the behavioral level in different types of visually mediated orientation tasks.

THE CONTROL OF HOVERING FLIGHT POSITION AT MOVING DUMMY FLOWERS IN THE HAWK MOTH *MACROGLOSSUM*. D.Varju*, Yan Zhou, M.Pfaff, Lehrstuhl für Biokybernetik, Universität Tübingen, D-74 Tübingen, FRG.

The feeding hawk moth *Macroglossum* hovers in front of flowers and follows them when they are moved by wind. The control of flight position has been investigated in the laboratory. Dummy flowers consisted of a blue disk and a tube filled with honey solution which opened in the centre of the disk. Both tube and disk could be moved independently towards and away from the hovering moth. Position control relative to the moving dummy is mediated by visual cues and mechanosensory inputs from the proboscis. When disk and tube are moved in phase animals follow the dummy very accurately. When the disk is moved alone (tube still) the performance is not much reduced, in contrast to moving the tube alone (disk still). The elaborate feedback control system with two error sensing devices underlying the position control has been analyzed. Anatomical investigations revealed structures on the proboscis which may provide the mechanosensory inputs.

IN FLIGHT DETECTION OF WATER BODIES: SENSORY MECHANISM OF AQUATIC BUGS. R. Schwind, Zoology Institute, University of Regensburg, D-8400 Regensburg, FRG

On dispersal, water bugs leave their aquatic habitats and fly in search for new bodies of water. Experiments with flying backswimmers (*Notonecta glauca*) have shown, that they detect bodies of water by the reflected polarized UV-light: Polarized UV-light with horizontally aligned e-vector induces downward flight and finally a plunge reaction. In a small ventral eye region which looks forward and down when the animal is flying, there is a special orientation of the microvilli of the two UV-cells of each ommatidium: the microvilli of these cells are horizontal and vertical respectively, thus providing a two-channel analyzer system which enables the animal to distinguish polarized UV-light reflected by water surfaces from unpolarized UV-light. Similar regional eye specializations and similar reactions to polarized UV-light were also found in the water boatman *Corixa punctata*.

TIME-CONTROLLED PREFERENCE IMPROVES THE EXPLORATION OF VISUAL OBJECTS IN *DROSOPHILA*. K.G. Goetz, Max-Planck-Institut für biologische Kybernetik, Spemannstrasse 38, D-7400 Tübingen, FRG.

Search for rewarding sites in a habitat is often accomplished by trial-and-error exploration of visible structures. To assay the preference in a choice between two inaccessible objects, a wingless fruitfly is placed on a circular disc surrounded by water. The objects are shown in opposite positions outside the disk. An account of the attempted runs towards each of the objects is obtained by automatic tracking. Equidistribution of the frequency of these runs suggests a significant lack of preference even in a choice between extremely different objects. The temporal sequence of the runs shows, however, that the equidistribution is achieved by sustained spontaneous alternation of the preferred target. The fly keeps running to and fro for hours, a behavior reminding on the indecision of Buridan's ass between two heaps of hay.

The present strategy of search suggests two general considerations. (1) Equidistribution of the selection frequency in a choice experiment may conceal the ability of an animal to discriminate between the presented objects. A reliable proof of the statistical independence of successive choices is often missing in reports on pattern recognition and learning. (2) Sustained permutation of the target prevents the fly from being 'captured' by the next best object. It is tempting to compare this effect with sustained spontaneous depth reversal in human perception which helps to overcome one-sided interpretations of ambiguous figures such as the Necker cube.

VISUAL CONTROL OF STRAIGHT FLIGHT IN *DROSOPHILA MELANOGASTER*. R. Wolf* and M. Heisenberg, Würzburg Univ., Würzburg, F.R.Germany

Maintaining a given orientation is a basic requirement of locomotion. Models of the underlying mechanisms envisage a motor output which corrects an error signal in a negative feedback loop. In such models the course is assumed to be straight in the absence of disturbances.

Drosophila in stationary flight at the torque compensator generates syndirectional yaw torque in response to moving visual patterns. This "optomotor response" is thought to serve in course control. Refined recording techniques now show that under undisturbed closed loop conditions with visual patterns (flight simulator) flight is neither straight nor controlled by the optomotor response. The fly generates a succession of torque pulses usually alternating in polarity. The resulting motion of the panorama does not elicit optomotor responses. The optomotor controller is unresponsive to motion in the direction to be expected from the endogenous turns (but is fully responsive to motion in the opposite direction). Mean flight direction is kept straight by the appropriate polarity of torque pulses. Possibly, non-directional acceleration is used as error signal.

In the flight simulator flies have the tendency to keep a single stripe in a frontal position. As an explanation the different internal gain of the optomotor response for front-to-back and back-to-front motion has been invoked. In as much as endogenous torque modulations do not elicit optomotor responses this idea must be rejected. Again, the fly keeps the stripe in the frontal visual field by the appropriate polarity of torque pulses using, in this case, position information as "error signal".

WATER RELATIONS OF GLACIER DWELLING COLLEMBOLA FROM THE TYROLEAN CENTRAL ALPS. G. Eisenbeis*, E. Meyer, Department of Biology, Joh.Gutenberg-University, D-6500 Mainz, FRG and Department of Biology, University, A-6020 Innsbruck, Austria

Four species of glacier Collembola from the Ötztal Alps were collected to measure their transpiration rates at various microclimatic conditions and their ability for compensating transpiratory water loss. The true glacier dwelling species *Onychiurus* 'sp. G' and *Isotoma* 'sp. G' indicated the highest rates of water loss (375 %/h, 280 %/h at 0%r.h./22°C). *Isotomurus palliceps* and *Entomobrya* sp. living at the margin of the glacier on firn or on the moraine seem to be more tolerant to desiccating conditions (83 %/h, 26 %/h). As expected from the specific transpiration rates the permeability values of *Onychiurus* 'sp. G' (400-800 $\mu\text{g}/\text{cm}^2 \cdot \text{h} \cdot 0.133 \text{ kPa}$ at lower humidities) are about one order of magnitude higher than those of *Entomobrya* spec. (70-100 $\mu\text{g}/\text{cm}^2 \cdot \text{h} \cdot 0.133 \text{ kPa}$). Under field conditions glacier dwelling Collembola must be able to compensate water loss by absorption through their ventral tube. In *I.palliceps* the uptake rate at 2°C (+ 60-80 %/h) is about 5-7 times higher than the corresponding transpiration rate.

COLD-INDUCED TISSUE CHANGES INFLUENCE GLYCEROL METABOLISM IN AN ARCTIC INSECT. Olga Kukal* and John G. Duman, Department of Biological Sciences, University of Notre Dame, Notre Dame, Indiana 46556, USA

Larvae of *Gynaephora groenlandica*, a long-lived moth endemic to the high arctic, are perennially freeze tolerant even in absence of cryoprotective glycerol. Consequently, we examined the link between glycerol production and cold-induced tissue changes. Extended exposure (>2 months) of larvae to near zero or freezing temperatures resulted in mitochondrial degradation which was reversible upon warm-acclimation (<1 week). Mitochondrial changes were correlated with reduced oxygen uptake, lowered cytochrome c concentration and glycerol synthesis. Larvae accumulated glycerol while hypometabolic in the summer or anoxic during winter with the result of an increased cryoprotection.

CALCULATION OF CUTICLE TEMPERATURE AND DIFFUSIVE RESISTANCES FOR EVAPORATION OF WATER IN SMALL SOIL ARTHROPODS BY COMPUTER AIDED HEAT FLUX ANALYSIS MODIFIED WITH DALTON'S FORMULA. G. Eisenbeis, Department of Biology, Joh.Gutenberg University, D-6500 Mainz FRG

The relationship of a small arthropod to the physical properties of its environment is a very complex problem. Cuticle temperature and the rate of transpiration depend mainly on such variables as air temperature and relative humidity, wind speed, permeability of the integument for water, the net heat input by radiation and convection and the geometrical parameters of the body.

Four energy components (sensible heat, long wave radiation, latent heat and metabolic heat) have been combined to an energy flux budget equation. The analysis depends among others on the premises that the body surface area is known and the rate of evaporation is constant. The method allows calculation of the body temperature both for totally wetted ($r_{\text{cut}}=0$) and unwetted animals (normal transpiration). Then the approach provides the diffusive resistances r_{tot} , r_{cut} and r_{air} . In addition, it is possible to calculate the transfer coefficients and the relative contribution of the components to the energy budget.

DEVELOPMENT OF A JUVENILE HORMONE RADIOIMMUNOASSAY. W.G. Goodman* and D.C. Coy, Department of Entomology, University of Wisconsin-Madison, Madison, WI 53706 USA.

A method for the synthesis of juvenile hormone III-thyroglobulin conjugate was developed which yielded an epitope density of 104 mol of juvenile hormone (JH) per mol of carrier protein. The resulting antiserum displayed minimal cross-reactivity with JH metabolites including JH acids, JH diols, and analogs but substantial cross-reactivity between JH homologs. Minimal sensitivity of the assay toward racemic JH III was 50 picograms. Using enantiomerically enriched, high radiospecific activity [³H]-JH II as a probe increased the sensitivity of the assay toward and the cross-reactivity between the three racemic JH homologs. In competition studies, this ligand was equivalently displaced by JH I, II, III. The use of the enantiomerically enriched probe also increased sensitivity of the assay toward the natural enantiomer of JH III and racemic JH O. The natural enantiomer of JH III was not as well recognized, indicating enantiomeric specificity toward the unnatural enantiomer. Employing different radiolabeled homologs resulted in changes in binding specificity. A method for preparing biological samples for RIA utilizing thin layer chromatography was developed. A mixture of JH homologs from biological extracts could be separated and assayed using continuous development thin layer chromatography. Biological blanks (hemolymph samples known to contain essentially no JH) did not interfere with the assay when this procedure was employed.

CHARACTERIZATION OF TOTAL AND JUVENILE HORMONE ESTERASE-SPECIFIC mRNA ISOLATED FROM LAST INSTAR LARVAE OF *TRICHOPLUSIA NI* (NOCTUIDAE), Mietek Wozniak and Grace Jones, Dept. of Entomology, University of Kentucky, Lexington, KY 40546, USA.

Total mRNA from eight developmental time points of last larval instar of *Trichoplusia ni* has been isolated. The transatability of the mRNA in a cell-free rabbit reticulocyte lysate system has been studied. The concentration of total mRNA is relatively high during the first half of the last stadium, when the message for storage proteins appears, and later the level of mRNA declines by 50-70%. Electrophoretic analysis of translation products of total mRNA has shown the presence of several highly abundant mRNAs which are present and translatable through the entire last stadium. Polyclonal antisera against one of the major hemolymph isoforms of JHE (pI 5.5) was prepared. The level of mRNA encoding juvenile hormone esterase was investigated by quantifying the immunoprecipitated JHE translation product.

Supported by NIH DK 39197

cDNA CLONES FOR A JUVENILE HORMONE SUPPRESSIBLE PROTEIN ASSOCIATED WITH LARVAL METAMORPHOSIS, Grace Jones, Department of Entomology, University of Kentucky, Lexington, KY, 40546.

During larval metamorphosis of *Trichoplusia ni* an acidic, 76,000 dalton protein becomes highly abundant in the hemolymph. Topical application of juvenile hormone to larvae results in suppressed abundance of the protein. A cDNA clone bank was prepared from day 2, fifth instar larvae in a transcription vector. A differential probe of mRNA from normal vs. JH treated larvae was used to identify clones from JH-suppressible mRNAs. These identified clones were then transcribed *in vitro* and the mRNAs translated in an *in vitro* rabbit reticulocyte lysate system. Polyclonal antibodies raised against the protein were used to identify the corresponding protein among translation products. Several positive clones were identified, and the region of the insert corresponding to the protein N-terminus was sequenced. Three possessed a sequence which coded for an N-terminus identical with that determined for the mature protein. Upstream from the N-terminus codon was an apparent coding sequence for a signal peptide of 20 amino acids. Supported by NIH DK 39197.

HORMONAL REGULATION OF PHENOLOXIDASE AND DOPA DECARBOXYLASE SYNTHESIS FOR MELANIZATION IN *MANDUCA SEXTA*. Kiyoshi Hiruma* and Lynn M. Riddiford, Department of Zoology, University of Washington, Seattle, WA 98195, U.S.A.

The absence of juvenile hormone (JH) at the time of head capsule slippage (HCS) in the final larval molt of *Manduca sexta* induces the deposition of premelanin granules containing prophenoloxidase (pro-PO) into the newly forming cuticle 13 hr later. When the ecdysteroid titer declines, the enzyme is activated and melanization occurs 3 hr before ecdysis. This granular PO was found to consist of 4 90 KD isozymes, all of which are glycosylated. When JH was absent at HCS, the epidermis began to synthesize the pro-PO 6 hr later: incorporation of the pro-PO into the new cuticle coincided with the deposition of the granules. Application of JH I up to 4 hr after HCS inhibited the onset of or further epidermal synthesis of pro-PO. Dopa decarboxylase (DDC), is also required for melanization. Two putative genomic clones for the DDC gene have been isolated and characterized and are being used to determine the hormonal regulation of the timing and amplitude of synthesis of this enzyme. Supported by NSF and NIH.

STRUCTURE AND EXPRESSION OF A *MANDUCA SEXTA* LARVAL CUTICLE GENE HOMOLOGOUS TO *DROSOPHILA* CUTICLE GENES. J.E. Rebers* and L. M. Riddiford, University of Washington, Seattle, WA. USA.

A genomic clone was isolated from the tobacco hornworm, *Manduca sexta*, by virtue of its similarity to a *Drosophila* larval cuticle gene. Hybrid-selection experiments using this clone show that it encodes a 14 kD protein, LCP-14, which is precipitated by *Manduca* larval cuticle antiserum. We have sequenced both genomic and cDNA clones for the LCP-14 gene. A conceptual translation of the cDNA sequence shows that the LCP-14 protein is similar not only to another *Manduca* cuticle protein, but also to *Drosophila*, *Sarcophaga*, and *Hyalophora cecropia* flexible cuticle proteins. Since these proteins are found in similar kinds of cuticle and have similar sequences, we conclude they are encoded by homologous genes. Supported by NIH grants to JER and LMR.

REGULATION OF ARYLPHORIN AND FEMALE-SPECIFIC STORAGE PROTEINS IN *Manduca sexta*. Bruce A. Webb* and Lynn M. Riddiford, Dept of Zoology, Univ. of Washington, Seattle, Washington, U.S.A. 98195.

Storage proteins are synthesized during larval life and utilized during adult development for the formation of imaginal tissues. We have isolated cDNA clones for two storage proteins, arylphorin and a predominantly female-specific protein, of *Manduca*. A comparison of the developmental expression of these RNAs and synthesis of the proteins by the fat body shows that the regulation is at the transcriptional level. The onset of arylphorin expression was shown to be dependent on nutrient level, whereas its shut-off during a molt and at wandering is due to both the lack of nutrients and rising ecdysteroids. The female-specific protein is differentially expressed in males and females with the onset of expression in females dependent on the decline in juvenile hormone in the final larval instar. In males expression begins at wandering but is not induced by the wandering ecdysteroid peak. Supported by NRSA 5T32 GM 07270 and N.S.F. DCB 85-10875.

ISOLATION OF THE ECLOSION HORMONE GENE FROM THE TOBACCO HORNWORM, *MANDUCA SEXTA*. F.M. Horodyski*, J.W. Truman, and L.M. Riddiford, Department of Zoology, NJ-15, University of Washington, Seattle, Washington, 98195, USA.

Eclosion hormone (EH) is a 62 amino acid neuropeptide whose primary action is to control ecdysis in insects. We isolated the EH gene from a *Manduca sexta* genomic library by screening with an oligonucleotide probe based on the known sequence of the peptide. The gene was identified by sequencing a 997 bp fragment of the genomic clone which hybridizes to the oligonucleotide probe. A portion of the translated sequence matches exactly with the known peptide sequence from amino acids 5 to 62. Just upstream from amino acid 5 is a potential 3' splice sequence. This 997 bp probe hybridized to a single band in a genomic Southern indicating that the EH gene is single copy in the *Manduca* genome. In addition, this probe hybridizes to a 940 nt RNA from developing adult brains. Temporal aspects of EH gene expression will be discussed.

This research was supported by the USDA.

SYNTHESIS AND PROCESSING OF VITELLOGENIN IN THE MOSQUITO *Aedes Aegypti*. A. S. Raikhe* and G. Sarojini, Department of Entomology, Michigan State University, East Lansing, Michigan 48824, U.S.A.

We showed that mosquito vitellogenin (VG) consisted of two subunits, 200-kDa and 65-kDa. Both subunits are phosphorylated and glycosylated. Their carbohydrate moieties are high-mannose oligosaccharides. In this study, using poly(A)+RNA from vitellogenic mosquitoes and an *in vitro* translation assay, we found that both subunits originated from a single primary precursor of 220-kDa. This polypeptide was recognized by monoclonal antibodies directed to either a small subunit, 65-kDa, or a large one, 200-kDa. In the presence of the microsomal fraction, the size of this common precursor increased to 230-kDa. The next step in the processing of VG was revealed by inhibition with tunicamycin. This drug caused accumulation of two polypeptides, 48-kDa and 180-kDa, recognized by subunit-specific monoclonal antibodies. *In vitro* pulse-chase experiments confirmed that 48-kDa and 180 kDa polypeptides represented unprocessed small and large VG subunits respectively. Glycosylation and phosphorylation were accounted for the final increase in the size of VG subunits.

THE DEVELOPMENT OF AN IMMUNOGEN FROM METHOPRENE, A NON-IMMUNOGENIC INSECT GROWTH REGULATOR. J.V. Mei*, C.-M. Yin, Department of Entomology, L.A. Carpino, Department of Chemistry, University of Massachusetts, Amherst, MA, USA, 01003.

The insect growth regulator, methoprene, is widely used as a control agent and a research tool for the investigation of juvenile hormone-like activities in insects. The many field applications of methoprene require the monitoring of residues in environmental samples. Existing techniques for methoprene residue analysis are costly, labor intensive, and time consuming. The development of immunological assays for methoprene would greatly facilitate its detection in the field.

Since methoprene is a small, non-immunogenic molecule, it must be covalently attached to a large carrier molecule to generate an immunological response. An immunogen has been developed which retains the features of the IGR, namely a methoxy and an ester function. The immunogen consists of methoprene acid linked as an ester to a spacer group, which is in turn linked to a carrier protein. Two methods of conjugating methoprene to a protein via activated esters were studied. The first method used a N-hydroxysuccinimide ester derivative and attached 53 molecules of methoprene per molecule of protein. A second method used a water soluble activated ester of methoprene and conjugated 30 molecules of the IGR per molecule of protein. Preliminary results indicate that the polyclonal antibodies raised against the immunogen in BALB/c mice are highly specific for methoprene.

TRANSFER RNA AND tRNA GENE OF SILKWORM, *Bombyx mori*. K. Matsuzaki* and I. Oh'hara. The Sericultural Experiment Station, Tsukuba City, Ibaraki 305 and School of Medicine, Kinki University, Osaka 589, Japan

Silk fibroin is synthesized in the posterior silk gland of the silkworm. As to characterization of tRNA from the posterior silk gland of the normal silkworm, it has been clarified that tRNA from the posterior silk gland consists of a specific one to the posterior silk gland and another constitutive to the cell. Furthermore, it was confirmed that an amount of fibroin produced in the posterior silk gland is proportional to the amount of tRNA specific to the posterior silk gland. With reference to the normal silkworm such as N134xCl35, the trimolt silkworm, the giant silkworm (Ohwashi) and the mutant silkworm inhibiting fibroin synthesis symbolized as Nd and Nd-s, every ratio of silk gland specific tRNA to constitutive tRNA corresponded to the cocoon shell weight implying the amount of fibroin. The tRNA of Nd and Nd-s mutant did not indicate the presence of silk gland specific tRNA in a large amount, although it appeared abundantly in tRNA such as glycine tRNA and alanine tRNA of the posterior silk gland from the normal silkworm. In order to understand how alanine tRNA and glycine tRNA are controlled at the level of gene in Nd and Nd-s mutant, alanine tRNA and glycine tRNA were cloned and characterized by restriction and M₁₃ sequencing.

ACID PHOSPHATASE ISOZYMES IN *ONCOPELTUS FASCIATUS* (DALLAS) (HEMIPTERA:LYGAEDIDAE). D. Feir* and D. Beck, Department of Biology, St. Louis University, St. Louis, MO 63103, USA.

In an effort to determine the pattern of acid phosphatase in milkweed bugs and the effects of juvenile hormone on acid phosphatase quantity & isozymes, fourth, fifth, and adult instars of known age were sacrificed. An additional group of fifth instars was treated with S-methoprene (Zoecon Corp., CA). Four grams of each group of bugs were homogenized in acetate buffer and Triton X-100 at 4°C. The samples were centrifuged, precipitated with (NH₄)₂SO₄, redissolved, desalted, and placed on a CM-cellulose column. Elution was with Tris-HCl buffer and protein fractions were collected. After dialysis, the peaks of acid phosphatase activity were run on a DEAE-exchange column and elution was with a salt gradient. Each step of the purification was monitored with protein and acid phosphatase assays. The last step was to submit the fractions to polyacrylamide gel electrophoresis and to stain for acid phosphatase. Six isozymes of acid phosphatase were obtained and three were unique to the 14 day adult female.

ARYLPHORIN OF THE GYPSY MOTH, *LYMANTRIA DISPAR*: TWO DISTINCT ROLES IN DEVELOPMENT. S.T. Karpells*, R.E. Dompencal-Rivera, D.E. Leonard and J.G. Kunkel, Zoology and Entomology Departments, University of Massachusetts, Amherst, Massachusetts, U.S.A. 01003.

In the gypsy moth, *Lymantria dispar*, concentration of arylphorin (Ap), the predominant larval serum storage protein, fluctuates in relation to the molting cycle-- peaking at each apolysis and declining to lower amounts towards ecdysis. An allometric relationship between Ap accumulation and weight gain supports a role in adult development. While weight increases 3.5 fold per instar the Ap titer increases at twice that rate, resulting in a domination of the serum protein profile by Ap in the metamorphic instar of the female particularly. This high rate of increase for Ap is not observed for lipophorin.

Additionally a sexual dimorphism of the instar of metamorphosis (VI in female but V in male) leads to higher Ap titer (67 mg/ml) in the metamorphic female. This is consistent with greater need for storage intermediates in the female for egg production. Twice the amount of Ap is present in *L. dispar* females than in other lepidopterans of comparable stage. This would compensate for the observed absence of female-specific hexameric storage protein in *L. dispar*. (Supported in part by grants from the USDA)

BIOSYNTHESIS AND METABOLISM OF A BLUE VERY HIGH DENSITY LIPOPROTEIN IN *HELIOTHIS ZEA*.

Norbert H. Haunerland* and William S. Bowers, Department of Entomology, University of Arizona, Tucson, AZ 85721, USA.

The corn earworm, *Heliothis zea*, has two major storage proteins: arylphorin, commonly present in several insect orders, and a unique blue chromoprotein. The latter is a very high density lipoprotein (VHDL) and contains biliverdin as a chromophore. It seems to be specific for Noctuidae. Unlike other hexameric storage proteins, the VHDL ($M_r = 560,000$) is composed of 4 subunits and contains 8.2 % lipid and 2 molecules biliverdin. It is synthesized in the fat body of actively feeding fifth instar larvae and released into the hemolymph. The biosynthesis is suppressed by juvenile hormone. The VHDL reaches concentrations of up to 20 mg per ml hemolymph, before it is selectively taken up by fat body tissue, newly formed around the gut at the beginning of the wandering stage. The VHDL is completely sequestered into the new central fat body, giving it a brilliantly blue color, and stored there in crystalline protein granules. The larval, peripheral fat body however remains white and does not incorporate any storage protein. During pupal development the central fat body disintegrates and the VHDL is hydrolyzed by proteolytic enzymes, thus supplying amino acids needed for the synthesis of adult structures. This unique blue protein allows to distinguish between two kinds of morphologically and functionally different fat body tissue: The peripheral, larval tissue, active in protein biosynthesis, and the central fat body, serving principally as a storage organ.

SOME CHARACTERISTICS OF CUTICULAR PHENOLOXIDASES IN THE COCONUT PEST, *ORYCTES RHINOCEROS*. T. Thangaraj, M. Aruchami*, R. Jeyaraj and C.A. Vasuki, Department of Zoology, Kongunadu Arts and Science College, Coimbatore, 641029, India.

The enzymes Trypsinase and Laccase have been separated from the cuticle of the coconut pest, *Oryctes rhinoceros*. The enzymes were purified by gel filtration on Ultragel AcA34. The characteristics of the purified enzyme was studied towards various substrates, pH optima, temperature and in the presence of various chemicals. The enzyme was identified in the acrylamide gel. The possible role of these enzymes has been discussed as proposed by Anderson (1981).

DEVELOPMENT OF THE GYPSY MOTH, LYMANTRIA DISPAR: STAGING AND JUVENILE HORMONE ACTIVITY. S. Tanaka*, M.T. Chang, And D.L. Denlinger, USDA Forestry Sciences Laboratories, Delaware, Ohio 43015, USA, and Department of Entomology, Ohio State University, Columbus, Ohio 43210, USA.

We have noted several morphological and behavioral changes during the final larval instar of L. dispar that can serve as developmental markers for endocrinological studies. Maximum weight is attained in the middle of the stadium, and this is followed in sequential order by a reduction in frass production, cessation of feeding, and initiation of silk production. In both sexes, the attainment of maximum weight, the reduction in frass production, and the beginning of silk production are particularly useful staging landmarks.

Series of hemolymph samples were collected from staged last stadium larvae as well as pupae of both sexes. Juvenile hormone (JH) activity was determined using the Galleria bioassay. Changes in JH activity and juvenile hormone esterase (JHE) activity will be discussed in relation to development.

REGULATION OF JUVENILE HORMONE (JH) III SYNTHESIS BY ISOLATED CORPORA ALLATA (CA) OF ADULT FEMALE CRICKETS, GRILLIUS BIMACULATUS (ENSIFERA: GRILLIDAE). K.H. Hoffmann*, R. Wennauer and L. Kassel, Department of Zoology, University of Ulm, 7900 Ulm, FRG.

CA from adult female G. bimaculatus exhibit rates of JH III synthesis which are closely correlated with oocyte maturation. JH III treatments in vivo (injection of 0.5 to 5 µg JH III) cause a stimulation of JH synthesis. In vitro incubation of CA in medium containing JH III in high concentrations (10^{-5} to 10^{-4} M) suppressed de novo JH synthesis (incorporation of ^{14}C -acetate) in spontaneously active glands. Treatment of inactive glands with physiological amounts of exogenous JH III (10^{-8} to 10^{-6} M) did not stimulate JH III synthesis, but led to an increase in the amount of methyl farnesoate (MF). This increase is due to a de novo synthesis.

Farnesol, a precursor of JH III, inhibits the incorporation of ^{14}C -acetate into JH III. However, a dramatic increase in the amount of intraglandular MF was observed after farnesol treatment. A limited epoxidative capacity seems to lead to such abnormally high MF levels.

An allatotrophic effect of 20-OH-ecdysone in vivo becomes apparent within 24 h after injection. However, no stimulation was observed when isolated CA were maintained for 3 to 4 h in medium containing ecdysteroids. Supported by the DFG (Ho 631/11-1).

RESPONSE OF MALE CORPORA ALLATA TO OVARIAN STIMULATION IN DIPLOPTERA PUNCTATA ESCHSCHOLTZ (BLATTARIA: BLABERIDAE). A.P. Woodhead and B. Stay*, Department of Biology, University of Iowa, Iowa City, Iowa, U.S.A. 52242.

In this study we ask whether the smaller and less active corpora allata (CA) of males can respond to the ovary with a cycle of juvenile hormone (JH) synthesis as female CA are known to do (Rankin and Stay, 1984, Gen. Comp. Endocrinol. 54:382). Szibbo and Tobe (1982, Gen. Comp. Endocrinol. 46:533) have shown that male CA implanted into allatectomized females synthesize JH at a low rate which supports vitellogenesis but results in delayed oviposition.

We have found that single pairs of male CA implanted into allatectomized females without ovaries synthesized JH at low rates (11 pmol h^{-1}). One or two pairs of male CA implanted into allatectomized females with ovaries reached peaks of JH synthesis of 40 pmol h^{-1} (on day 5) and 50 pmol h^{-1} (on day 6), respectively, and then declined. Oviposition began on days 8 and 9 following implantation of one and two pairs of male CA, respectively. The maximum rate of synthesis by controls, female CA implanted into allatectomized females, was $85 \text{ pmol h}^{-1} \text{ pair}^{-1}$ on day 5; oviposition began on day 7. Thus the ovary does elicit a cycle of JH synthesis by male CA but a smaller one than in female CA.

EXTRACTION AND PURIFICATION OF ALLATOSTATIN FROM WHOLE HEADS OF DIPLOPTERA PUNCTATA. M.A. Khan*, A. Lange and S.S. Tobe, Department of Zoology, 25 Harbord Street, Toronto, Ontario, Canada M5S 1A1.

One of the most important factors controlling juvenile hormone (JH) biosynthesis in adult females of the pacific cockroach, D. punctata is allatostatin (AST). This putative neuropeptide is produced in the brain and transported directly to the corpus allatum by way of nerves and released in the vicinity of the gland cells, thereby restraining gland activity. A protocol for the isolation and purification of AST from whole heads is described. The *in vitro* radiochemical assay for JH biosynthesis was used for monitoring AST activity. Purification techniques included the utilization of sep-pak cartridges and reverse-phase high performance liquid chromatography. This work is supported by a NATO Science Fellowship from the Netherlands Organization for Pure Research.

THE ROLE OF FEEDING AND MATING IN THE REGULATION OF JUVENILE HORMONE (JH) SECRETION IN ADULT FEMALE LEUCOPHAEA MADERAE. D. Aclé*, V.J. Brookes, and R. Feyereisen, Department of Entomology, Oregon State University, Corvallis OR 97331-2907.

In Diploptera a participation of the corpora allata (CA) in the mating behavior of the females seems highly improbable since the female is rather inactive during mating (Roth and Willis, 1955). Allatectomy has no effect on mating in females of this species and feeding is not a major constraint on oocyte development. Leucophaea is different in that both feeding and mating are necessary for optimal oocyte growth. The response of the female of Leucophaea to the courting male may be under the control of the CA. Activity of the CA has been quantified by measuring the secretions of the CA in vitro using the method described by R. Feyereisen (1985). Experiments showed that feeding increases CA activity to about $1.9 \pm .1 \text{ pmol JH/hr/pair}$ of glands until the roaches are mated (11-12 days after emergence). CA of unfed virgin females are inactive. After mating the activity of the CA reached a peak of $60 \text{ pmol JH/hr/pair}$ of glands. Oocyte measurement of mated females indicates that the oocyte length is a good indicator of CA activity.

OCTOPAMINERGIC INHIBITION OF JUVENILE HORMONE BIOSYNTHESIS IN THE CORPORA ALLATA OF THE COCKROACH DIPLOPTERA PUNCTATA. C.S. Thompson, K.J. Yagi*, Z.-F. Chen and S.S. Tobe, Department of Zoology, University of Toronto, Toronto, Ontario, Canada M5S 1A1.

The phenolamine, octopamine (Oct), is widely distributed in the nervous system of insects and numerous studies have established an important role for Oct as a neurotransmitter and a neurohormone. We report on observations which suggest that Oct may be involved in the control of juvenile hormone (JH) biosynthesis by the corpora allata (CA). 1. HPLC analysis of homogenates of the CA show that Oct is present at a mean level of $0.11 \pm 0.01 \text{ pmol/CA}$. 2. Following incubation of CA in medium containing Oct ($5 \times 10^{-5} \text{ M}$) there is a 7-fold increase in the cAMP content of the CA and a significant decrease in rates of JH biosynthesis compared to control values, in agreement with previous studies which have shown that treatments which elevate the cAMP content of the CA (high K^+ saline, brain extract, forskolin + IBMX) also inhibit JH biosynthesis. 3. Monitoring of membrane potential of CA cells with microelectrodes reveals that Oct elicits a pronounced hyperpolarization. These experiments do not demonstrate whether Oct acts directly on CA cells or on nerve terminals within the CA to elicit the release of an unidentified allatostatin. These studies were supported by NSERC grant #3-656-120-60 to S.S. Tobe.

ROLE OF CYCLIC NUCLEOTIDES AND CALCIUM IN BASAL AND NEUROPEPTIDE-MODULATED JUVENILE HORMONE SYNTHESIS BY LARVAL CORPORA ALLATA OF THE TOBACCO HORNWORM, MANDUCA SEXTA. C.U. Allen*, W.P. Janzen and N.A. Granger, Department of Cell Biology and Anatomy, University of North Carolina, Chapel Hill, NC 27599 USA.

Calcium and cyclic nucleotide second messengers appear to be involved in the basal and neuropeptide-modulated synthesis of JH I, JH III and their acids by last larval instar Manduca sexta corpora allata (CA). For these *in vitro* studies, synthesis was quantified by JH I and JH III radioimmunoassays (RIAs) specific for the homologs and their acids. An assessment of the effects of agents which alter internal cyclic AMP (cAMP) levels suggested that increases in JH I (acid)/JH III (acid) synthesis involved elevated intracellular levels of cAMP. Dose dependent accumulations of cAMP (measured by RIA) were observed in response to a phosphodiesterase inhibitor and a JH III allatotropic neuropeptide. By contrast, cAMP decreased 40-50% in response to a JH I allatostatic neuropeptide. Extracellular calcium affected basal synthesis levels by CA early in the instar but not after pupal commitment, and JH III ATF stimulation of the CA required 10^{-3} to 10^{-4} M extracellular calcium. Results from investigations of the effects of calcium channel blockers and ionophores and the measurement of calcium in CA cells have confirmed the critical role of calcium in the regulation of CA activity.

A HIGH AFFINITY, HIGH MOLECULAR WEIGHT JH BINDING PROTEIN IN THE HEMOLYMPH OF DROSOPHILA MELANOGASTER. L. Shemshedini and T. G. Wilson, Department of Zoology, University of Vermont, Burlington, VT 05405, USA.

Using the hydroxyapatite (HAP) binding assay, a juvenile hormone III binding protein has been identified in the hemolymph of post-feeding third instar larvae of Drosophila melanogaster. This binding component was shown by photoaffinity labeling and gel filtration to be a single protein with a native molecular weight of 400 kDa. It has an equilibrium dissociation constant for JHIII of 1.45 nM, an affinity 10-times higher than that of similar proteins from other insects. It exhibits high specificity for the natural hormone, with the following order of binding affinities: JHIII >> JHII > JHI > JHIII acid >> methoprene. It is separate from another component in the hemolymph that binds methoprene nonspecifically. These binding characteristics will be compared to those of a cytosolic JH binding component.

JUVENILE HORMONE-BINDING PROTEINS OF THE TWO-STRIPED GRASSHOPPER. P.E. Roberts*, C.L. Murphy+, L. S. Jefferies, and B.S. Winder, Department of Entomology and the Cell and Molecular Biology Program, Colorado State University, Fort Collins, CO 80523, USA, and +USDA-ARS IABBBRL, Gainesville, FL 32604, USA.

Juvenile hormone (JH) controls the synthesis of vitellogenin by the fat bodies of a variety of insects including the two-striped grasshopper, Melanoplus bivittatus. A number of proteins are involved in the transport of JH to target cells, the conversion of JH into a signal for new transcription, and the regulation of JH levels by its modification to the acid and/or diol. Fat bodies in culture medium picked up radiolabeled JH that became bound by nuclear proteins. A putative JH receptor was detected in fat bodies of both adult males and females, but males had maximal binding on day three while the females reached a maximum at day seven. Characterization of the proteins from the hemolymph and from fat body cytosol and nuclei confirmed that a protein with Mr of 72,000 was common to both fat body and hemolymph. Several other proteins were unique to only one compartment. By characterization of the JH-binding proteins, we hope to gain information about the relationship of their JH-binding domains and their evolution. Funded by NIH AI18470-01AI TMP and Biomedical Research Support Grants from Colorado State University.

JUVENILE HORMONE CONTROLS CHROMOSOMAL SEX DETERMINATION IN APHIDS. Dinah F. Hales, School of Biological Sciences, Macquarie University, N.S.W. 2109, Australia.

In aphids, parthenogenetic females can produce either female offspring with an XX sex chromosome complement or male offspring with an XO sex chromosome complement. Male determination results from the elimination of one of the X chromosomes during the maturation of the parthenogenetic egg. In natural conditions, this occurs usually in the decreasing photoperiods and temperatures of autumn. Experiments by Mittler et al. (1979, J. Insect Physiol. 25, 219-226) showed that treatment of intact aphids with the juvenile hormone analogue, kinoprene, prevented male determination, suggesting that male determination could not occur when juvenile hormone level was high. This has now been confirmed by experiments in which aphids were treated with precocene, and then given kinoprene replacement therapy. Precocene treatment caused total or partial allatectomy in the aphid Myzus persicae, with a concomitant switch to ovulation of male eggs. Short term kinoprene therapy delayed male production in allatectomized aphids, and delayed or eliminated male births in aphids whose corpora allata were affected but not destroyed by precocene. It is concluded that the behaviour of the X chromosomes during the maturation division of the egg is controlled by the level of juvenile hormone.

HORMONAL REGULATION OF EGG PRODUCTION IN CRICKETS.

W. Loher*, F.C. Baker and D.A. Schooley, *Department of Entomology, University of California, Berkeley, CA 94720 and Zoecon Corporation Research Laboratories, Palo Alto, CA 94304.

In the cricket, Teleogryllus commodus the corpora allata produce only Juvenile Hormone III (JH). During the larval stages, JH maintains larval characters, whereas in adult females the hormone is supposed to be responsible for oocyte maturation. However, allatectomy during the early penultimate (7th) instar resulted after the next molt in adultoid crickets which not only displayed perfect reproductive behavior, but also developed several normal-sized eggs. Similarly, allatectomized last larval instars molted into adults and produced ca. 20% of an ordinary egg load.

Since analysis of whole-body extracts from operated crickets by gas chromatography - mass spectrometry failed to show JH, thereby ruling out possible JH-carry over pools, alternative explanations are discussed.

REGULATION OF CORPORA ALLATA IN BLATTELLA GERMANICA (L.) (DIPTYOPTERA: BLATTELLIDAE) IN RELATION TO THE FEMALE REPRODUCTIVE CYCLE. M. Gadot* and C. Schal, Department of Entomology, Rutgers University, Cook College, New Brunswick, New Jersey 08903, USA.

The corpora allata (CA) of the female B. germanica go through extreme changes in both size and activity during the reproductive cycle. In mated females, these changes are precisely correlated with oocyte maturation and the subsequent gestation.

In vitro incubations of CA taken from females in different stages of the reproductive cycle, with or without farnesoic acid (FA), reveal the following:

(1) During oocyte maturation, the rate of JH-III biosynthesis is always lower than the maximal rate obtained in the presence of FA, indicating a rate-limiting step prior to formation of FA;

(2) During gestation, complete suppression of JH synthesis, with or without FA, is followed by morphological changes indicating CA degeneration. These events reverse in the next oocyte maturation cycle.

These results are compared with similar studies of other cockroach species and the migratory locust.

ROLE OF JUVENILE HORMONE IN WINGMORPH DETERMINATION IN
GRYLLUS RUBENS Anthony J. Zera, Zoology Dept., Univ. of
Toronto, Toronto, Ontario, Canada M5S 1A1

Experiments reported here were performed on the wing polymorphic cricket, *Gryllus rubens*, to investigate the potential regulatory role of juvenile hormone (JH) in wingmorph determination. Previous studies had shown that topical application of JH during the last stadium redirects development from long to short wings. Last stadium JH esterase activity was substantially higher in presumptive long-winged (LW) versus short-winged (SW) individuals. High JH esterase activity strongly co-segregated with long wings in F_1 -interstock and in F_2 backcrosses between stocks nearly pure-breeding for long or short wings. JH titers (measured in collaboration with Drs. Colette and Alain Strambi, C.N.R.S., Marseilles, France) declined more rapidly in LW versus SW crickets during the first third of the last stadium. Results suggest that variation in JH titers, produced at least in part by variation in rates of JH hydrolysis during the last stadium, specify alternate winglength phenotypes in *G. rubens*. The potential role of variation in rates of JH biosynthesis (measurements currently in progress in collaboration with Dr. S. S. Tobe, Zoology Dept, Univ. of Toronto) in generating variation in JH titers during the last stadium will also be discussed.

INVESTIGATION OF THE MODE OF ACTION OF A BENZYL-1,3-BENZODIOXOLE ON REPRODUCTION IN THE MEDITERRANEAN FRUIT FLY, *CERATITIS CAPITATA* (WIEDEMANN) (DIPTERA:TEPHRITIDAE)
F. Chang*, C.L. Hsu, and L. Jurd, Department of Entomology, University of Hawaii at Manoa, Honolulu, Hawaii 96822 U.S.A.

Topical or oral administration of J2581 (5-ethoxy-6-(4-methoxyphenyl)methyl-1,3-benzodioxole) to newly-emerged *C. capitata* females resulted in a (1) temporary delay in ovarian development (2) decrease in eggs oviposited (3) failure of larvae to eclose. Examination of hemolymph proteins in benzodioxole-treated females by SDS-PAGE revealed that vitellogenin synthesis was not affected.

Competitive protein binding assays were conducted using hemolymph and ovarian tissues in order to evaluate the effects of J2581 on putative JH-sensitive binding sites. Radiochemical assays using isolated corpora allata preparations are presently being conducted in an effort to reveal whether juvenile hormone III biosynthesis is inhibited. The results so far obtained will be presented.

ISOLATION OF INSECT JUVENILE HORMONE III AND METHYL FARNESOATE FROM THE PLANT *CYPERUS IRIA*. F. C. Baker*, Y. C. Toong†, C. C. Reuter, L. W. Tsai, and D. A. Schooley, Sandoz Crop Protection, Zeecon Research Institute, Palo Alto, CA 94304; †Universiti Sains Malaysia, School of Chemical Sciences, 11800 Penang, Malaysia.

Juvenile hormone (JH) III was isolated from field collected specimens of the Malaysian plant *Cyperus iria* (grasshopper's *Cyperus*; Cyperaceae). The electron impact mass spectrum of the product was identical to authentic JH III; furthermore, the plant JH III possessed the same (10R) configuration as insect JH III. Greenhouse grown *C. iria* plants contained $\approx 150 \mu\text{g}$ JH III/g fresh weight. Analysis of plant parts showed that stems plus leaves contained highest levels of JH III ($\approx 185 \mu\text{g/g}$) while roots and developing inflorescences contained $\approx 50 \mu\text{g}$ JH III/g and $30 \mu\text{g}$ JH III/g, respectively. None of the other known JHs could be detected, but we found substantial levels ($\approx 14 \mu\text{g/g}$) of methyl (2E,6E)farnesoate, a precursor of JH III, and putative JH of crustaceans.

Grasshopper (*Melanoplus sanguinipes*) nymphs reared on *C. iria* grew at a rate similar to control animals fed on wheat seedlings, but on moulting to adults the former showed morphogenetic effects reminiscent of treatment with excess JH (metathetely). Ovaries from *Cyperus*-fed females were markedly underdeveloped compared to those of controls.

INVESTIGATIONS INTO DIAPAUSE DEVELOPMENT OF THE SOUTHWESTERN CORN BORER, *DIATRAEA GRANDIOSELLA* DYAR (LEPIDOPTERA: PYRALIDAE). G. Michael Chippendale, Department of Entomology, University of Missouri, Columbia, Missouri 65211, USA.

Diapause development refers to the physiological changes occurring during diapause that must be completed before morphogenesis can resume. Evidence to support the multifaceted nature of diapause development will be drawn from experiments carried out on *D. grandiosella*, which enters a juvenile hormone (JH)-dependent diapause as a fully grown larva. Diapause development in this insect proceeds rapidly under high temperatures and long days (e.g., 30°C LD 16 hr : 8 hr). However, diapausing larvae in the field have been shown to lose their sensitivity to a diapause-maintaining short day by the time of the winter solstice. The state of wing disc development and spermatogenesis and the frequency of stationary ecdyses during diapause will be described. In addition, data will be presented about the titers of the following substances in early, mid, and late diapausing larvae: JH esterase; JH binding protein; diapause-associated protein; lipophorin; and storage proteins. The relationships that have been uncovered indicate that complex processes control the maintenance and termination of diapause. These studies were supported in part by NSF grants.

AN IMIDAZOL DERIVATIVE (KK-42) BREAKS DIAPAUSE IN THE LARVAE OF PHARATE FIRST INSTAR. K. Suzuki*, T. Fujisawa, T. Nakamura, M. Kurihara (Applied Entomology, Faculty of Agriculture, Iwate University, Morioka 020, Japan) and E. Kuwano (Department of Agricultural Chemistry, Kyushu University, Fukuoka 812, Japan).

The eggs in the silkworm of *Antheraea yamamai* and the gypsy moth of *Porthesia dispar* enter diapause at pharate first instar about 10 - 15 days after oviposition. These eggs initiated diapause were applied by any concentration of KK-42 which has been synthesized as anti-JH, and were chilled at 2 - 5 °C for a short period (10 days). When the treated eggs were incubated at 25 °C, a number of larvae hatched in about 10 days. In addition, the effects of KK-42 on diapause termination decreased largely by the simultaneous application of methoprene or S-31183. This function of KK-42 is the first finding in entomology and could be useful to elucidate the mechanism of diapause in pharate first instar.

ECDYSTEROID ACTIVITY IN THE GYPSY MOTH, *LYMANTRIA DISPAR*: IDENTIFICATION OF PROTHORACICOTROPIC HORMONES FROM EMBRYO THROUGH ADULT. E. P. Masler*, T. J. Kelly, B. S. Thyagaraja†, R. E. Davis, R. A. Bell, and A. B. Borkovec. Insect Reproduction Laboratory, United States Department of Agriculture, Agricultural Research Service, Beltsville, Maryland, 20705, USA, and †RSRS Central Silk Board, C. R. Nagar, Karnataka, India.

As in other lepidopteran species, *L. dispar* metamorphosis is directed by the brain through neuropeptide and steroid messengers. A two-phase *in vitro* prothoracic gland incubation has been coupled with an ecdysteroid radioimmunoassay to detect and quantify prothoracicotropic hormone (PTTH) activity in tissue extracts. PTTH activity is present in extracts of brain and retrocerebral ganglia and is detected in all stages from embryo through adult. Considerable cross-reactivity exists among the various developmental stages and two molecular weight species of 5,000 and 20,000 Daltons have been identified. There is variation in the levels of activity during development with highest levels detected in larval tissue. Embryonic PTTH shows biochemical dissimilarity with post-embryonic PTTH with regard to chromatographic behavior and response to denaturants. The significance of PTTH distribution at various stages of development and possible role of the brain in oocyte maturation will be discussed.

STRUCTURE OF BOMBYXIN (4K-PTTH), A NEUROPEPTIDE FROM THE SILKMOTH, *BOMBYX MORI*. H. Nagasawa*, A. Suzuki, H. Ishizaki† and T. Blundell††, Department of Agricultural Chemistry, The University of Tokyo, Bunkyo-ku, Tokyo 113, Japan, †Biological Institute, Nagoya University, Chikusa-ku, Nagoya 464, Japan, and ††Department of Crystallography, Birkbeck College, London University, Malet Street, London WC1E 7HX, England.

Bombyxin is a brain neuropeptide of the silkworm, *Bombyx mori*, and has been called 4K-prothoracicotropic hormone (4K-PTTH) because it could stimulate prothoracic glands of *Samia cynthia ricini* to produce ecdysone. Bombyxin-II, one of various molecular forms of bombyxins, was isolated and characterized. The complete amino acid sequence of bombyxin-II was established by the sequence analysis of the intact molecule and of peptides derived by various enzymatic digestions and by determination of FAB mass spectra of the N- and C-terminal fragment peptides. It consists of two peptide chains, A-(20 residues) and B-chains (28 residues), connected by disulfide bonds like insulin. The mode of the disulfide bridges was determined by characterizing thermolysin peptides containing cystine residue(s) to be A(6)-A(11), A(7)-B(10) and A(20)-B(22). This structure was confirmed by chemical synthesis of the whole molecule. The close primary structure of bombyxin-II to insulin (40% homology) permitted us to construct the three-dimensional model.

ISOLATION AND CHARACTERIZATION OF OVARIAN ECDYSIOTROPIC FACTORS (OEF) FROM THE FEMALE MOSQUITO, *Aedes aegypti*. Shogo Matsumoto*¹, Mark R. Brown², Akinori Suzuki¹, Arden O. Lea²; ¹Dept. of Agricultural Chemistry, University of Tokyo, Bunkyo-ku, Tokyo 113, Japan; ²Dept. of Entomology, University of Georgia, Athens, GA 30602, USA.

Ecdysiotropic factors (OEF) from heads stimulate ovaries to secrete ecdysone in the mosquito. Four active fractions have been isolated from 880,000 heads of *Ae. aegypti*, with conventional column chromatography, ion-exchange HPLC, and reversed-phase HPLC. The activity during purification was monitored by *in vivo* assays. When injected, as little as 12 pg of purified OEF elicited yolk deposition in both *Ae. aegypti* (anautogenous), fed blood and immediately decapitated, and *Ae. atropalpus* (autogenous), decapitated at eclosion. Purified OEF stimulates isolated ovaries of *Ae. aegypti* to secrete ecdysteroids. The factors are basic peptides with an estimated molecular weight of 10,000, and analysis of the amino acid composition of one OEF indicated 92 residues.

DIFFERENTIAL EFFECT OF 20-HYDROXYECDYSONE IN LARVAL-PUPAL TRANSFORMATION OF LEPIDOPTERA AND DIPTERA. E. Shaaya, The Volcani Center, Bet-Dagan 50-250, Israel.

Changes in RNA synthesis in the epidermis of last larval instar larva of *Ephesia cautella* and *Manduca sexta* (lepidoptera) and *Calliphora vicina* (Diptera) were followed. For about 30 h just prior to wandering stage, total RNA synthesis was depressed. The shutdown of RNA synthesis including that of rRNA appears to be one of the first metamorphic responses to ecdysteroid in the absence of juvenile hormone and permits the loss of larval ribosomes. In *Calliphora* this change caused a reduction of 60% of the bulk RNA in the cells. Following this period, the wandering stage, pupally committed epidermal cells synthesize a new type of RNA termed hetero-disperse nuclear RNA. The appearance of this RNA species, when RNA synthesis first resumes, is one of the first manifestations of pupal commitment. Juvenile hormone delayed the larval-pupal transformation and prevented these changes in RNA synthesis. *In vitro* 50 ng/ml 20-hydroxyecdysone (20-HE) was necessary and sufficient to cause the depression of RNA synthesis in day 1 *Manduca* epidermis. On the contrary the change to pupal commitment induced by 24 h exposure of day 2 epidermis to 500 ng/ml 20-HE caused a significant increase in total RNA synthesis.

ROLE OF 20-HYDROXYECDYSONE IN REGULATING GROWTH AND DIFFERENTIATION OF THE DERMAL GLANDS OF *MANDUCA SEXTA*, K.L. Horwath* and L.M. Riddiford, Department of Zoology, University of Washington, Seattle, WA 98195

At larval and pupal ecdyses, segmentally paired dermal glands secrete a proteinaceous cement layer to coat the epicuticle. Electrophoretic analyses of the products of the large secretory cell within each gland show that its polypeptide composition is stage specific and after pupal commitment, also segment specific. Fluorograms from pulse labeling of glands indicate that the larval proteins are made throughout the 4th instar, with enhanced synthesis coincident with the molting surge of ecdysteroids. Pupal products are synthesized in the 5th larval instar beginning at the commitment peak of ecdysteroids and increasing during the prepupal surge in ecdysteroids. Developmental time course of synthesis of the various pupal proteins differs within and between segments. Ecdysteroid induced protein synthesis was confirmed by *In Vitro* culturing of glands from newly ecdysed 4th (2.5 µg/ml 20-hydroxyecdysone (20HE) and 1 µg/ml juvenile hormone) and, day 2 5th instars (0.5 µg/ml 20HE). Differential regulation of the pupal products was also observed *In Vitro*. Furthermore, secretory cells undergoing larval to pupal transformation (d1 5ths) when implanted into intermolt host animals, synthesized both larval and pupal products simultaneously during the ecdysteroid induced molt.

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DIFFERENTIAL REACTIVITY TO 20-HYDROXYECDYSONE BETWEEN MEIOTIC AND MITOTIC SPERMATOGENETIC DIVISIONS OF THE HORNWORM *MANDUCA SEXTA*. Michael Friedländer* and Stuart E. Reynolds. Department of Biology, Ben Gurion University of the Negev, Beer Sheva, Israel* and School of Biological Sciences, Bath University, Bath, U.K.

In *Manduca sexta*, the progression of meiotic prophase towards metaphase is induced by the post-wandering peak of 20-hydroxyecdysone (20HE). Spermatocytes remain blocked at prophase in abdomens isolated before the peak but undergo meiotic metaphases in those isolated after the peak. The meiotic block is removed in the isolated abdomen by either implanting the prothoracic glands explanted from the same individual or by injecting 20HE. Duration of the unblocking effect of 20HE is dose-dependent; the larger the dose injected, the more extended the effect. The spermatogonial mitotic metaphases, however, were not blocked by corresponding either abdomen isolation or 20HE injections. Spermatogenetic mitoses differ in this respect, therefore, from the somatic mitoses which have been reported to react differently to fluctuations of the 20HE titer.

ACTIVATION AND TRANSPORT OF SPERM DURING MATING IN LEPIDOPTERA. Julian Shepherd* and Nancy Hague, Department of Biological Sciences, State University of New York at Binghamton, Binghamton, NY USA 13901.

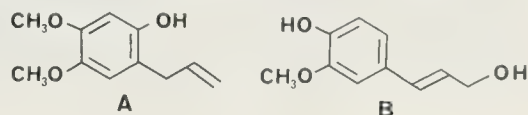
Activation of the anucleate sperm during mating in Lepidoptera has been shown in saturniid moths to be induced by a polypeptide produced by the male's accessory glands. In spite of a previous report, this mechanism now appears to be general throughout the Lepidoptera, occurring in more primitive microlepidoptera as well as a number of more advanced macrolepidoptera including butterflies. The mechanism has apparently evolved uniquely to activate the anucleate sperm.

This activation is essential to the first phase of sperm migration in the female: the movement of the sperm out of the spermatophore. Through use of inhibitors of sperm motility and female muscular activity, we have shown that the exit of sperm from the spermatophore requires only sperm motility, whereas further transport through the seminal duct to the sperm storage organ, the spermatheca, requires only muscular movements by the female. This control by the female of sperm loading has certain evolutionary implications.

ACCUMULATION OF PHENYLPROPANOIDS IN THE RECTAL GLANDS OF MALE ORIENTAL FRUIT FLY, *DACUS DORSALIS*.

R. Nishida, K.H. Tan*, M.A. Serit*, N.H. Lajis**, A.M. Sukari**, S. Takahashi and H. Fukami. Pesticide Research Institute, Kyoto University, Kyoto, 606 Japan. *Univ. Sains Malaysia, Penang. **Univ. Pertanian Malaysia, Selangor, Malaysia.

Two phenylpropanoid compounds, 2-allyl-4,5-dimethoxyphenol (A) and coniferyl alcohol (B) were identified as the major volatiles in the body tissue of male Oriental fruit fly, *Dacus dorsalis*, captured at various field sites in West Malaysia. When laboratory-reared males were fed with methyl eugenol, the two compounds built up within a few hours and were stored in the body tissue for several days. It was demonstrated that A and B were concentrated in the male's rectal glands and released in the air at dusk during mating period. Similar to methyl eugenol, A showed a potent attractancy to the male flies in field tests. Pheromonal and allomonal effects of the phenylpropanoids were examined.



THYROXINE INDUCED LARVAL AND OVARIAN DEVELOPMENT IN THE SILKWORM, *BOMBYX MORI* L. B.S. Thyagaraja*, T.J. Kelly, E.P. Masler, R.B. Imberski**, and A.B. Borkovec, Insect Reproduction Lab, USDA, ARS, Beltsville, MD 20705. *RSRS, Central Silk Board, C.R. Nagar, Karnataka, India. **Dept. of Zoology, University of Maryland, College Park, MD 20742.

Thyroxine was fed to silkworms, along with mulberry leaves, during various stages of larval growth to determine the efficacy of enhancing the silk cocoon ratio for commercial exploitation. Hormone fed at either larval instar II or IV had essentially the same effect on silk production and cocoon formation as hormone fed continuously from instar I through V. In each treatment scheme, silk and cocoon character were superior to that of controls. The growth induction effect of thyroxine is revealed by an increased larval growth rate from 11-fold at instar II to 27-fold at instar V in the group treated during instar II. In addition, the total length of the larval stage was reduced by 30 to 40 hours by the thyroxine treatment. A nearly 1½-fold increase in hemolymph protein and a 5-fold increase in hemolymph ecdysteroid levels on day 10 of larval instar V and pupal day 4, suggest that thyroxine influences both protein and steroid metabolism. Oocyte growth and development were also accelerated as demonstrated by an enhancement of growth rate and increased protein and ecdysteroid levels.

THE ROLE OF JUVENILE HORMONE IN THE REGULATION OF CALLING BEHAVIOR AND PHEROMONE PRODUCTION IN FEMALES OF THE TRUE ARMYWORM MOTH, *PSEUDALETIA UNIPUNCTA* (HAW.) (LEPIDOPTERA: NOCTUIDAE). M. Cusson* and J.N. McNeil, Département de Biologie, Université Laval, Ste-Foy, Québec, Canada G1K 7P4.

In females of the true armyworm moth, *P. unipuncta*, the presence of intact corpora allata (CA) is essential to the initiation of both calling behavior and pheromone production. Females without CA do not call and do not produce pheromone, but injection of juvenile hormone (JH) into allatectomized females restores these activities to normal levels. This is in contrast with results from related studies pertaining to other moth species.

As pheromone release activities do not begin until basal oocytes have reached a critical size, we speculated that JH might exert its effect through an intermediate ovarian hormone, possibly an ecdysteroid. However, ovariectomized females call and produce pheromone normally, thus indicating that JH must act directly on the brain to control these activities.

The relationship between JH production rates and the initiation of calling behavior will be discussed within the context of seasonal migration.

IS GLUTATHIONE PEROXIDASE ACTIVITY PRESENT IN INSECTS?

Sami Ahmad* and Ronald S. Pardini, Department of Biochemistry, University of Nevada-Reno, Reno, NV 89557-0014, USA.

Unlike the mammalian species, in insects, a Se-dependent glutathione peroxidase (Se-GPOX) is absent. Therefore, we examined the possibility that the non-Se-dependent glutathione transferase (GT) may be acting analogous to the Se-GPOX in destroying lipid/organic hydroperoxide (LOOH). In the reduction of LOOH to LOH, GSH is oxidized to GSSG which in a coupled reaction with glutathione reductase (GR) is recycled as GSH with the reducing equivalents provided by NADPH. To demonstrate the GT's peroxidative activity, we used enzyme preparation from mid-fifth instar larvae of *Trichoplusia ni*, and as substrate, cumene hydroperoxide. Enzyme activity expressed in units (nmol of NADPH oxidized/min-mg protein) ranged from 54.3 to 57.3 in 600g and 850g larval supernatants. In the nuclear, microsomal and cytosolic fractions the activities were 74.0, 34.6 and 13.2 units, respectively. No activity was detected in the mitochondrial fraction. We are now extending this work to other insect species. Based on analogy to mammalian enzymes and their substrate specificity, the insect glutathione peroxidase activity is likely to be due to GT. This work was supported by USDA competitive grant 86-CRCR-1-2038.

CHOLESTEROL ABSORPTION AND LIPOPROTEIN SYNTHESIS IN THE MIDGUT OF *LOCUSTA MIGRATORIA*. R. Singhal* and H.C. Agarwal, Department of Zoology, University of Delhi, Delhi-110007, India.

Absorption of ^3H -cholesterol and its binding with lipoproteins was studied *in vitro* by using isolated alimentary canal preparations in *L. migratoria*. Adult male locusts were force-fed ^3H -cholesterol or ^{14}C -protein hydrolysate or both as an emulsion. After 2 hrs. the entire alimentary canal was removed and midgut incubated in saline for 2 hrs. Detection of ^{14}C -proteins in the midgut showed that it is able to synthesize proteins. The lipoprotein synthesized in the midgut is released into the medium. In ^3H -cholesterol fed insects the cholesterol was released from the midgut in the saline bound to a lipoprotein. Double-labelling experiments showed that cholesterol is released bound to the lipoprotein synthesized by the midgut. A lipoprotein identical in electrophoretic mobility and binding cholesterol was also present in hemolymph.

SITOSTEROL METABOLISM *IN VIVO* AND *IN VITRO* IN *HELIOTHIS ARMIGERA* AND *LOCUSTA MIGRATORIA*. R. Rath*, R. Singhal, V. Goel and H.C. Agarwal, Department of Zoology, University of Delhi, Delhi-110007, India.

Sitosterol dealkylation was studied in *H. armigera* and *L. migratoria* both *in vivo* and *in vitro*. Freshly hatched insects were reared on an artificial diet containing 0.1% sitosterol. ^3H -sitosterol was added to the diet of the 6th instar *Heliothis* and adult *Locusta*. Fat body, hemolymph, midgut, gut contents and carcass were taken after 2 hrs and sterols analysed by GLC and HPLC. In all cases cholesterol and sitosterol were detected. For *in vitro* studies the entire alimentary canal was taken out 2 hrs after ^3H -sitosterol intake and midgut incubated in saline. Both midgut and media contained cholesterol. Fat body when incubated in a media containing ^3H -sitosterol also converted it to cholesterol thus showing that sitosterol is dealkylated to cholesterol in these insects, both *in vivo* and *in vitro*.

HORMONAL INFLUENCE OF *IN VIVO* AND *IN VITRO* PHEROMONE PRODUCTION IN MOTHS V. Srooker* and A. Rafaeli. Department of Entomology, Faculty of Agriculture, Rehovot 76100, Israel.

Sex pheromone production in *Heliothis armigera* and *Spodoptera littoralis*, which normally occurs during the scotophase, was inhibited when moths were ligated between the head and the thorax. This inhibition was overcome by injections of brain-complex extracts resulting in the production of pheromone components. Moreover, *S. littoralis* hormone was capable of inducing the production of Z(11)-hexadecenal by *H. armigera* females. *In vitro* *H. armigera* ovipositor tips incorporated C^{14}/H^3 from incubation media containing C^{14}/H^3 -sodium acetate. This incorporation was stimulated by 97% in the presence of brain-complex extracts. The degree of sodium acetate incorporation by glands was dependent on the time of incubation and age of female glands.

METABOLISM OF POLYUNSATURATED FATTY ACIDS IN INSECTS. D.W. Stanley-Samuelson*, R.A. Jurenka, C. Cripps, and G.J. Blomquist. *SRI International, Menlo Park, CA 92540 and Department of Biochemistry Univ. of Nevada, Reno, NV 89557.

We have investigated the metabolism of polyunsaturated fatty acids (PUFAs) in several insect species. The waxmoth *Galleria mellonella* is unable to synthesize, and hence, requires dietary C18 PUFAs, a proportion of which is used to synthesize longer-chained and more unsaturated C20 fatty acids. The cricket *Teleogryllus commodus* is among 15 species that can synthesize 18:2 *de novo*. The 18:2 can be elongated and desaturated to form 20:3 and 20:4, both of which can be further metabolized into prostaglandins and other oxygenated metabolites. Two mosquitoes *Culex pipiens* and *tarsalis* lack the enzymes required to further metabolize C18 PUFAs; these species require dietary C20 PUFAs. *Drosophila melanogaster* appears to neither synthesize nor require C18 or C20 PUFAs.

THE ROLE OF LIPID TRANSFER PARTICLE IN FLIGHT RELATED DIACYLGLYCEROL MOBILIZATION. M.C. Van Heusden*, R.O. Ryan, and J.H. Law, Department of Biochemistry, University of Arizona, Tucson, Arizona 85721 USA.

In *Manduca sexta*, lipids are transported via hemolymph by the lipoprotein, high density lipophorin (HDLp). In adult *M. sexta*, diacylglycerol (DG) is the main fuel for flight. During flight, a nonapeptide adipokinetic hormone (AKH) is released from the corpora cardiaca which induces mobilization of DG from fat body triacylglycerol stores. During loading of DG, HDLp binds several molecules of apolipophorin-III to become a low density lipophorin (LDLp). *M. sexta* hemolymph lipid transfer particle (LTP) catalyzes net transfer of lipid between lipoproteins of different density *in vitro*. The possible function of LTP in the process of DG transfer from fat body to lipophorin was investigated. *In vitro* mobilization of DG from fat body by AKH, in the presence of HDLp and apoLp-III, was enhanced by LTP. However, the resulting lipid-loaded lipoprotein was not LDLp, but a new lipophorin species, very low density lipophorin (VLDLp, density = 1.02 g/ml). Furthermore, it was found that incubation of LDLp and LTP *in vitro* resulted in conversion of LDLp into VLDLp and HDLp. The results suggest LTP and VLDLp may function in physiological lipid transport processes in *M. sexta*. Supported by NIH grants GM 29238 and HL 34786.

COORDINATED ACTIONS OF Ca^{++} AND CYCLIC AMP IN MEDIATING ADIPOKINETIC HORMONE RELEASE FROM THE LOCUST CORPUS CARDIACUM. T. Pannabecker* and I. Orchard, Dept. of Zoology, Univ. of Toronto, Toronto, Ontario, Canada M5S 1A1.

Two adipokinetic hormones (AKHs) are synthesized and stored within the neurosecretory cells (NSCs) located in the glandular lobe of the locust corpus cardiacum. These hormones are released during prolonged flight and subsequently regulate metabolic substrate levels. Octopamine is the best candidate for the neurotransmitter controlling the release of these hormones and cyclic AMP (cAMP) serves as a second messenger for octopamine. Octopamine, forskolin, and 3-isobutyl-1-methylxanthine elevate cAMP levels of the NSCs in the presence or absence of extracellular Ca^{++} . However, AKH release evoked by these compounds is strictly dependent upon extracellular Ca^{++} . Thus release fails to occur in Ca^{++} -free saline despite normal elevations in cAMP. Voltage-sensitive Ca^{++} channels are present in the NSCs and Ca^{++} influx through these channels is directly associated with the process of AKH release. These data indicate that extracellular Ca^{++} plays a key role as an intracellular messenger in the process of AKH release and suggest that there is a functional requirement for Ca^{++} at a step distinct from and perhaps following cAMP production.

ISOLATION, CHARACTERIZATION, AND DISTRIBUTION OF AEDS RFamide PEPTIDES IN THE FEMALE MOSQUITO, *Aedes Aegypti*. Shogo Matsumoto¹, Mark R. Brown^{*2}, Joe W. Crim³, Arden O. Lea²; ¹Dept. of Agricultural Chemistry, University of Tokyo, Bunkyo-ku, Tokyo 113, Japan; ²Dept. of Entomology, ³Dept. of Zoology, University of Georgia, Athens, GA 30602, USA.

Peptides with the same RFamide C-terminal as FMRFamide (Phe-Met-Arg-Phe-amide), a cardioexcitatory neuropeptide in molluscs, were purified from heads. Three peptides were isolated with conventional column chromatography, ion-exchange HPLC, and reversed-phase HPLC. Immunoreactivity was monitored by RIA. One of the peptides, a decapeptide, was synthesized after sequence analysis. Chromatographic properties of the synthetic decapeptide confirmed the structure of the native peptide. FMRFamide-like immunoreactivity, presumably due to the presence of the isolated peptides, was detected in neurosecretory cells, neurons, and midgut endocrine cells of females. Immunoreactivity in extracts of heads, hemolymph, and midguts of females was quantified by RIA.

ACTIVATION OF FAT BODY GLYCOGEN PHOSPHORYLASE IN THE EASTERN LUBBER GRASSHOPPER. J.H. Spring* and G. Gade, Dept. of Biology, Univ. of Southwestern Louisiana, Lafayette, LA 70504, U.S.A.

Crude homogenates of corpora cardiaca (CC) from the lubber grasshopper, *Romalea*, are capable of activating glycogen phosphorylase in a dose-dependent manner. Phosphorylase activation was caused by two compounds, designated RoI and RoII, which were present in CC extracts in the ratio of 6:1. The compounds were separated by reversed-phase HPLC and shown to be peptides. For each peptide, the amino acid composition was determined, the primary structure elucidated, and the peptide synthesized. These synthetic peptides also activated glycogen phosphorylase in *Romalea* and permitted comparisons of their stimulatory activity on a molar basis. Significant activation occurred with 0.5 pmol of RoI and 1.25 pmol were needed for a maximum response. RoII showed significant activation with 0.2 pmol and maximal activation with 1.0 pmol although the maximum phosphorylase activation with RoII was significantly less than with RoI. Both RoI and RoII were released *in vitro* when CC were incubated in a saline containing high K^+ and Ca^{++} . This release does not appear to be affected by octopamine.

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THE PENTAPEPTIDE PROCTOLIN MAY MEDIATE ITS ACTIONS ON THE LOCUST OVIDUCT VIA INOSITOL PHOSPHOLIPID HYDROLYSIS. A.B. Lange* and I. Orchard, Department of Zoology, University of Toronto, Toronto, Ontario, Canada M5S 1A1

The lateral oviducts of *Locusta migratoria* are innervated by proctolin-containing motoneurons. Proctolin does not stimulate any changes in the endogenous levels of either cyclic GMP or cyclic AMP in the oviducts. However, proctolin ($10^{-8}M$) does stimulate the hydrolysis of inositol phospholipids, as judged by an increase in radioactivity associated with IP_1 and IP_3 in oviducts previously labelled with [^3H] myo-inositol. Lithium, an inhibitor of myo-inositol-1-phosphatase, potentiates the proctolin-induced accumulation of radioactivity in IP_1 .

Another product of inositol phospholipid hydrolysis is diacylglycerol, which remains within the plasma membrane and activates protein kinase C. Experimentally, protein kinase C can be activated in intact cells by means of monoacyl-derivatives of diacylglycerol such as 1-oleoyl-2-acetyl-glycerol (OAG) or by phorbol esters such as phorbol 12-myristate 13-acetate (TPA). Addition of either OAG or TPA to locust oviducts mimics the long-term action of proctolin, namely the induction of a basal contraction with intense phasic contractions superimposed.

These results lend preliminary support to the hypothesis that proctolin mediates its action via the hydrolysis of inositol phospholipids.

THE ROLE OF OCTOPAMINE IN THE ANTENNAL HEART OF THE COCKROACH. G. Pass*¹, G. Sperk², W. Hertel³, H. Agricola³, E. Baumann³ and H. Penzlin³,

¹ Institute of Zoology, University of Vienna, Austria;

² Institute of Pharmacology, University of Innsbruck, Austria; ³ Department of Animal Physiology, University of Jena, G.D.R.

The antennal heart in the head of *Periplaneta americana* is both a circulatory pump supplying the antennae and a neurohemal organ. Numerous neurosecretory axons, which probably originate from DUM-neurons in the suboesophageal ganglion, terminate within its ampullae. Extraordinarily high amounts of octopamine could be demonstrated in antennal heart homogenates by a radioenzymatic assay. Pharmacological and electrophysiological investigations indicate that this biogenic amine is involved in the regulation of the myogenic heart rhythm. The bulk of octopamine, however, is concentrated in the ampullae suggesting that it is released from the neurohemal area into the hemolymph. It is immediately pumped into the antennae and may function in regulating the antennal sensory system.

SOME PHARMACOLOGICAL PROPERTIES OF VICERAL AND SKELTAL MUSCLES IN INSECTS. J. Fukami* and N. Izawa. Laboratory of Biology, Meiji College of Pharmacy, Setagaya, Tokyo, 154, Japan, and Life Science Research Institute, Kumiai Chemical Industry, Kikugawa, Shizuoka, 439, Japan.

Pharmacological properties of visceral muscle contractions in the American cockroaches (*Periplaneta americana*) and EPSPs (excitatory postsynaptic potentials) recorded from skeltal muscles in the mealworm (*Tenebrio molitor*) were studied. Glutamate agonists exerted various responses. It was suggested that there were three types of responses according to the pharmacological aspects. The first was quisqualate type (type I), the second was ibotenate type (type II), and the third was kainate type (type III).

DYNAMICS OF INDOLEAMINES AND AND MELATONIN SYNTHESIZING ENZYMES IN *Periplaneta*: A POSSIBLE INVOLVEMENT OF INDOLEAMINES IN CIRCADIAN CLOCK REGULATION. M. Takeda, T. Natsukawa, Y. Matsuda and H. Nakagawa, Entomological Laboratory, Kobe University, Kobe 657 and Institute of protein research, Osaka University, Suita 565, Japan

We have demonstrated immunohistochemically the presence of indoleamines, serotonin and melatonin and a melatonin synthesizing enzyme, Hydroxyindole-O-methyltransferase (HIOMT) in the cockroach brain and the ventral cord (1,2). Since these play important roles in vertebrate circadian clocks, we investigated dynamics of these compounds in relation to the circadian clock regulation in cockroach. We here present 1) more precise mapping of melatonin and HIOMT in the cockroach central nervous system 2) circadian change, if exists, in various indoleamine and catecholeamine compounds detected by HPLC with ECD 3) the activity change in two melatonin synthesizing enzymes, serotonin N-acetyltransferase and HIOMT detected by a radioenzymatical method 4) correlation and non-correlation between compounds and enzymes examined and cockroach's locomotor activity.

1) Nishiitsutsuji-Uwo et al. (1984) Biomed. Res. 5; 211-224

2) Takeda et al. (1986) Biomed. Res. 6; 395-406

TIME MEASURING PROTEIN: TIMING OF BOMBYX DIAPAUSE TERMINATION. H. Kai* and T. Kawai, Faculty of Agriculture, Tottori University, Tottori, Japan 680.

When inactive esterase A4 (Ease A4), which was purified in column form crystals, was chilled at 5°C in vitro, the enzyme activity was suddenly elevated two weeks after the chilling, and was followed by a rapid fall; the sudden elevation in vitro is equivalent to that observed in vivo and coincident with the chilling period, the latter being indispensable for the diapause termination. In the combination chilling in vivo and in vitro, the enzyme was suddenly activated two weeks after the exposure to 5°C, irrespective of its exposure in vivo or in vitro. If the Ease A4 which had not been activated, because of short 8-day-chilling, was treated with guanidine-HCl and then underwent re-chilling, the treated enzyme required an additional two weeks for the reactivation.

The Ease A4 acts as an interval-timer; the activation may result from an autonomous structural change of the enzyme molecule which proceeds gradually in cold.

THE PHYSIOLOGICAL AND BIOLOGICAL ACTIVITY OF TWO COTTON ALLELOCHEMICS ON THE SPINY BOLLWORM EARIAS INSULANA BOISD. M. H. Mansour *, A. E. Aboul-Nasr (1) and E.M. Amr. National Research Centre Cairo, Egypt, Faculty of Science, Cairo University (1).

The spiny bollworm is a major cotton pest in Egypt; therefore, the larvae are subjected to a wide variety of cotton allelochemicals. The objective of this work was to describe the relationship between gossypol and gallic acid concentrations and larval growth with regard to utilization of food. Low dosages of gossypol and gallic acid acted as phagostimulants, while at higher concentrations they acted as phagodeterrents. Gossypol up to 1.9×10^{-3} molar and gallic acid up to 1.5×10^{-3} molar inhibited growth by reducing the efficiency of conversion of digested and ingested food.

PREY-PARALYSING MECHANISM OF A POTTER WASP POMPILUS ZEUS. G.Sundara Rajulu*, N.Gowri and P.Kadirvelu, Department of Zoology, Bharathiar University, Coimbatore 641046, India.

The potter wasp Pompilus zeus deposits lepidopteran caterpillars in the cells of its nest to serve as food for its developing larvae. Before deposition the caterpillars are completely paralysed by stings. The paralysis of the caterpillars is found to be due to the decrease in the acetylcholine (Ach) profiles of the nervous system. Controls have $0.799 \pm 0.002 \mu\text{mol}/\mu\text{g}$ of Ach which reduces to $0.264 \pm 0.002 \mu\text{mol}/\mu\text{g}$ after stings. The reverse happens with the Gamma Amino Butyric acid (GABA); the control active caterpillars have $3.48 \pm 0.29 \mu\text{mol/g}$ of GABA in the central nervous system and the content of this neuroinhibitor increases to $7.76 \pm 0.39 \mu\text{mol/g}$ in those caterpillars stung by the wasps. The physiology of these variations is discussed in relation to the paralysis of the prey-caterpillars.

SUBSTRATE ANALOGUES FOR PHOTOAFFINITY LABELING OF CHITIN SYNTHETASE.

M.G. Peter*, H. Wiederstein and F. Schweikart, Institut für Organische Chemie und Biochemie der Universität Bonn, D-5300 BONN, FRG.

Isolation of chitin synthetase is necessary for elucidation of the structure and mechanism of the enzyme. With the aim to provide reagents for the covalent labeling of the protein, we report on a synthesis of N-diazoacetyl-glucosamine as a photoaffinity substrate analogue. In addition, approaches towards the preparation of N-diazoacetyl-uridinediphospho-glucosamine will be discussed.

DIGESTION OF CHITIN, CELLULOSE AND OTHER POLYSACCHARIDES BY BEETLES (COLEOPTERA). Ch. Jeuniaux* and M.F. Jaspar-Versali, Zoological Institute, Liège University, B-4020 Liège Belgium.

Using both classical biochemical methods and histo-enzymological techniques, different hydrolytic activities against polysaccharides were searched for in the digestive system of several beetle species. Histo-enzymological data provided useful informations concerning the tissular origin and the localization of the hydrolases so far pointed out.

Carabid beetles are characterized by a broadly diversified digestive enzymatic equipment, with high chitinases, cellulase, amylase and laminarinase activities. Such diversified digestive abilities, which are interpreted as a primitive characteristic, allow the exploitation of diet with maximum efficiency.

In most other beetle families studied so far, the digestive enzymatic equipment appears more specialized, the secretion of some glycanases being un conspicuous and probably lost. For instance, chitinase secretion is lacking in the digestive tract of Scarabaeidae, Geotrupidae and Dermestidae, whereas cellulase (of glandular origin, at least) was not found in Scarabaeidae, Geotrupidae and Dytiscidae. However, a diversified enzymatic equipment similar to that one found in Carabidae is obvious in some other families such as Silphidae and Pyrochroidae.

THE INVERTASE OF THE HOUSE CRICKET ACHETA DOMESTICUS L. (ORTHOPTERA: GRYLLOIDAE). L.H. Teo* and J.P. Woodring, Department of Zoology, National University of Singapore, Kent Ridge, Singapore & Department of Zoology & Entomology, Louisiana State University, Baton Rouge, Louisiana 70803, U.S.A.

The invertase of Acheta domesticus has a pH optimum around 5.6. A sigmoid temperature-activity curve was obtained when the temperature was raised from 20 to 45°C. The activation energy is 5,300 cal/mole. Both mercuric chloride and high temperature (50°C) caused inhibition of the cricket invertase. The 50% inhibition concentration of mercuric chloride is 59 μmole and the 50% inhibition time of 50°C is 45 minutes. Five days of starvation caused a fall of 25% of the total activity of the whole gut but the specific activity remained unchanged. The caecal tissues showed very high activity of the invertase. When the activity of the invertase in the contents of different parts of the gut was compared, the anterior hindgut showed the highest activity, followed by the crop, the caecum and the ventriculus.

STUDIES ON MID-GUT PHOSPHATASES AND NON-SPECIFIC ESTERASES IN DIACRISIA OBLIQUA (LEPIDOPTERA). S.Palanichamy* and P.Baskaran, P.G. & Research Department of Zoology, A.P.A. College of Arts & Culture, Palani - 624602, Tamil Nadu, India.

Phosphatases and non-specific esterases, representing hydrolytic enzymes have been carried out in the mid-gut region of final instar larva of Diacrisia obliqua which is a pest in Caster plants. These have been characterized biochemically in relation to effect of pH, substrate concentration and various chemicals. Phosphatases exhibited three pH optima, two at acid range (pH 3.0 and 5.0) and one at alkaline range (pH 9.0). Non-specific esterase showed the maximum activity at pH 7.0. Michaelis constant (K_m) and velocity maximum (V_{max}) for acid phosphatases are 1.32 mM and 1.11 $\mu\text{mole p-nitrophenol. mg protein}^{-1} \text{ h}^{-1}$ and for alkaline phosphatases, they were 1.11 and 1.22 respectively. The K_m and V_{max} for non-specific esterases were 1.32 mM and 0.46 $\mu\text{mole 1-naphthol mg protein}^{-1} \text{ 30 min}^{-1}$, respectively. The influence of chemicals varied in the mid-gut region of D. obliqua.

LEUCINE TRANSPORT IN THE INTESTINE OF HONEYBEES (*Apis mellifera* L., HYMENOPTERA: APIDAE) IN SUMMER.

K. Crailsheim, Institut für Zoologie, Abteilung für Stoffwechselphysiologie, Karl-Franzens-Universität, A-8010 Graz, Austria.

The transport of ^3H -labelled leucine within and out from the intestinal tract of the honeybee was investigated in vivo. Ingested leucine did not penetrate the wall of the crop (honey stomach) at any nutritionally significant rate. Independent on the molarity of leucine in the fed solution, absorption through the midgut wall was restricted mainly to the first two thirds and showed saturation kinetic. Transport rates were not influenced in the presence of glucose, glycine, arginine or glutamic acid, but were significantly lowered in the presence of isoleucine. These results indicate a carrier mediated transport system. Compared to bees in winter, foragers in summer showed a faster transport through the midgut wall.

Soon after injection or feeding ^{14}C -labelled leucine, $^{14}\text{CO}_2$ could be detected in the exhaled air, indicating significant oxidative metabolic fate of the amino acid. This latter findings are consistent with results about halflife of protein and the loss of injected amino acid, reported in an earlier study (Crailsheim 1986, J. Insect Physiol. 32, 629-634).

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POST-FEEDING DIURESIS IN ADULT *HELIOTHIS ZEA* BODDIE (LEPIDOPTERA: NOCTUIDAE). D. W. Bushman and J. O. Nelson, Department of Entomology, University of Maryland, College Park, Maryland, USA, 20742.

A post-feeding diuretic response has been observed in adult *H. zea* and measured by weight loss. Adult males and females lost 86% and 49%, respectively, of the weight of the ingested meal (WIM) during the first hour after feeding. Neck ligation immediately after feeding reduced the weight loss to 7% of WIM for both males and females. Surgical removal of the frontal ganglion immediately after feeding also resulted in a significant reduction in weight loss (10% of WIM) while sham controls had normal weight losses. Intraabdominal injections of homogenates of corpora cardiaca/corpora allata (CC/CA) into fed insects also reduced the 1 hour weight loss to 24% and 12% of WIM for males and females, respectively. Muscle tissue and the remaining tissues of the central nervous system lacked this antidiuretic activity in the assay. The common effect of ligation, frontal ganglionectomy or CC/CA homogenate injection was retention of fluid in the crop as determined by dissection and weighing the crop.

TRANSEPITHELIAL VOLTAGE MEASUREMENTS IN ISOLATED MALPIGHIAN TUBULES. K.W. Beyenbach* and D.J. Aneshansley, Depts. of Physiology and Agr. Engineering, Cornell Univ., Ithaca, N.Y. 14853. (USA)

Three methods to measure the transepithelial voltage are evaluated in isolated Malpighian tubules of the yellow fever mosquito, *Aedes aegypti*. In method I the lumen-to-bath voltage ($V_{\text{L-P}}$) is measured in isolated perfused tubules through a perfusion pipet lodged in the tubule lumen. Measured voltages are exclusively lumen-positive. In method II the output voltage (V_{out}) is measured in secreting tubules as the voltage between the Ringer bath and the fluid droplet secreted into an oil bath. This measurement yields positive and negative values. Both measurements assume open circuit conditions. However, this is not the case in method II where the analysis of the measuring circuit reveals 1) the peritubular water film of the oil-bathed tubule segment to affect the amplitude of V_{out} , and 2) the axial lumen resistance and the lateral resistance of the epithelial wall to affect the amplitude and the polarity of V_{out} . This conclusion is supported by method III where voltage is measured in secreting tubules via a microelectrode impaling the tubule lumen. The microelectrode voltage measurements ($V_{\text{T-M}}$) are always lumen-positive as in method I even though method II yields negative voltages (V_{out}) at the same time.

REGENERATION OF A PEPTIDERGIC NEUROHEMAL ORGAN IN THE LEPTOPTEROUS INSECT *MANDUCA SEXTA*. N. Agui*, C.T. McQueen, A.L. Westbrook, T.R. Flanagan and W.E. Bollenbacher, *Department of Medical Entomology, National Institute of Health, Shinagawa-ku, Tokyo 141 Japan, Department of Biology, University of North Carolina, Chapel Hill, NC 27514 USA.

In a simple organization of the cerebral peptidergic neurons of insects and because of their morphological analogy with the cerebral neuroendocrine axes of vertebrates, the neurosecretory cells (NSC) of *pers. intercerebralis-retrocerebral* complex of insects could be good models for investigating the regeneration of peptidergic neurons. With the availability of a monoclonal antibody to PTH of *Manduca* and by the employing allatectomy as a method of injuring the primary axons of PTH cells, the regeneration of axon of NSC and their formation of a new neurohemal organ has been investigated immunocytoologically during larval-pupal development after allatectomy. As results, the PTH neuron showed the capacity to regenerate a neurohemal organ, which apparently functions in a physiological manner to release PTH and thus drive postembryonic development. Because of the comparative ease with which this regenerative process can be followed, it would appear this system can be useful in understanding mechanistic aspects of the process by which this specialized type of neuron development and undergoes regeneration.

EPIDERMAL CELL BEHAVIOUR DURING WOUND HEALING IN *ONCOPELTUS FASCIATUS* (HEMIPTERA). G.L. Campbell, Department of Zoology, University of Western Ontario, London, Ontario, Canada N6A 5B7.

Damage to the integument of an insect elicits a particular response in the epidermal cells surrounding the wound: they become activated over a certain distance around the wound, they migrate towards the wound and subsequently spread over cell free areas until continuity is restored and finally they may divide. The exact pattern of activation, movement and division depends upon the nature of the wound. These patterns of cell behaviour are described and, in conjunction with further *in vivo* and *in vitro* studies, the range of factors influencing this behaviour is discussed. The strongest influence on activation and migration is damage to the cuticle and this is associated with factors released during melanisation of the wound and by haemocytes. Activation and low cell density are not sufficient conditions to stimulate the division of cells peripheral to wounds. These cells can be stimulated to divide by 20-hydroxyecdysone. Cell divisions are found within the wounded area (even when 20-hydroxyecdysone titre is low) and the condition required for such division appears to be disruption of epidermal continuity for a minimum length of time.

Supported by NSERC of Canada

THE STRUCTURE OF SEMINAL VESICLES OF THE TOMATO FRUIT WORM, *HELIOTHIS ARMIGERA* (HÜBNER) WITH REGARD TO SPERM MORPHOLOGY AND PHYSIOLOGY (LEPIDOPTERA: NOCTUIDAE). G. Amaldoss * and Chen Chuan Shang, Department of Biology, Fu Jen University, Hsinchuang 24206, Taipei, Taiwan, ROC.

The thin extensible tubular vasa deferentia of *Heliothis armigera* are usually expanded over part of their length to form seminal vesicles, which are male sperm storage organs distinct from testes, duplex glands and spermatophores if they are formed in the male reproductive tract. Seminal vesicles are mesodermal in origin, functioning as a repository for spermatozoa besides nurturing them with nutrients, sustaining them in the seminal fluid and possibly facilitating them in their maturing process. Contrary to earlier reports, seminal vesicles reveal a rich secretory epithelia and apocrine is seemingly the mode of secretion. The secretory epithelia consists of outer muscle layers, a prominent basement membrane penetrated by trachea, nerve endings and a single cell type epithelium. Synthesis of secretory materials and their release into the lumen are clearly seen. In the seminal vesicles Spermatozoa exhibit dimorphism. Eupyrene sperm appear to be in bundles and covered by dissolving cyst, while the apyrene sperm are found individually. Fine structure reveals incomplete spermatogenesis in the seminal vesicles. Spermatozoa are completely immotile in the seminal vesicles and remain so even after they are activated *in vitro*. So the factors that inhibit motility of spermatozoa *in situ* as in storage in seminal vesicles raise new questions about the role of seminal vesicles themselves. Possibly physiological conditions that are conducive for sperm activation and motility are not met within the seminal vesicles as in the case of duplex glands, another sperm storage organ of male *Heliothis armigera*.

PARASITOID ENCAPSULATION IN *DROSOPHILA MELANOGASTER*: GENETIC AND PHENOTYPIC TRADE-OFF RELATIONS. C. Mollema, Department of Population Biology, University of Leiden, The Netherlands.

Melanotic encapsulation is a general aspecific immune response against invading parasites in insects. Moreover, melanization takes place at many other parts of the insect's physiology, e.g., wound healing and puparium formation. Dietary manipulation using melanin precursors has shown already that these substances are limiting factors in insects. The biosynthesis of melanin is apparently a relatively expensive process. The present study shows genetic and phenotypic trade-off relations between melanotic encapsulation and respective fecundity and puparium formation in *Drosophila melanogaster*. The consequences of these trade-off relations are discussed, particularly the correlations between geographical origin and encapsulation capacity, which have been unexplained for many years.

RESPONSE CHARACTERISTICS OF DIRECTIONALLY SENSITIVE WIDEFIELD MOTION DETECTORS IN THE BRAIN OF THE HONEYBEE, *APIS MELLIFERA* AND THE WASP, *PARAVESPULA VULGARIS*. L.J. Goodman* and C.J.D. Pomfrett, Department of Biological Sciences, Queen Mary College, University of London, Mile End Road, London E1 4NS, United Kingdom and Department of Communication and Neuroscience, Keele University, Keele, Staffordshire, ST5 5BG, United Kingdom.

Some of the wide field motion sensitive descending interneurons in the brain of the honeybee, *Apis mellifera* and the wasp, *Paravespula vulgaris*, are directionally selective, responding only to motion in the preferred direction. Other neurons are directionally biased, responding differentially to the preferred and opposite (null) directions of motion. Analysis of the velocity responses of the neurons reveals the presence of a number of cells in each insect with similar directional properties but with markedly different peak velocity sensitivities. This suggests that range fractionation may be employed in wide field motion driven course control. The preferred direction of motion of the cells generally remains constant on changing stimulus velocity but the directional bias of a cell may change.

THE ROLE OF WIDE FIELD MOTION SENSITIVE DESCENDING INTERNEURONS IN VISUALLY MEDIATED COURSE CONTROL IN THE HONEYBEE, *APIS MELLIFERA*. M.R. Ibbotson* and L.J. Goodman, School of Biological Sciences, Queen Mary College, University of London, Mile End Road, London E1 4NS, United Kingdom.

Sixteen descending interneurons (DNs) showing phasotonic responses to wide field movement of the surround have been identified in the brain of the honeybee, *Apis mellifera*. Each neuron arborises in the pro and mesometathoracic ganglia and a number of them additionally arborise in the suboesophageal ganglion. Analysis of the responses elicited in each cell by simulated rotational and translatory wide field movement past both compound eyes shows that neurons are individually responsive to the motion of the surround induced by either roll, pitch or yaw. Roll detectors, for example, are sensitive to downward motion over the ipsilateral eye and upward motion over the contralateral eye, while they show no response to simulated translatory motion at any orientation. Pitch detectors are sensitive to vertical motion in the same direction over the frontal region of both eyes and show little response to simulated roll. Yaw detectors are responsive to rotational motion where there is regressive motion over the ipsilateral eye and progressive motion over the contralateral eye. Translatory motion elicits a small response to simulated forward flight.

VISUALLY INDUCED FLIGHT MANOEUVRES IN *MANDUCA SEXTA* (L.). G. Wendler* & U.J. Dombrowski, Zoologisches Institut der Universität, Tierphysiologie, Weyertal 119, D-5000 Köln 41, Federal Republic of Germany

In rest, tethered tobacco hornworm moths turn their heads and abdomens in reaction to optomotor stimulation. The head movements were analyzed (determination of the frequency response) in correlation with myograms of the d12 - a prothoracic neck muscle. This muscle is involved in yaw-roll movements of the head as shown by electrical stimulation. In flight, additional steering movements of all wings can be observed during optomotor stimulation. The corresponding changes of the flight motor pattern were described in detail. We found dramatic asymmetries in the number of spikes/burst and in the phase of activity between homologous muscles. - Unilateral changes of wing proprioceptor input however produced changes in wingbeat frequency but no asymmetries.

PHYSIOLOGICAL PROPERTIES OF CAMPANIFORM SENSORY NEURONS OF THE DIPTERAN WING BLADE. M.H. Dickinson, Department of Zoology, U of Washington, Seattle, WA, 98195.

The wing blade of many dipteran species contain eight identifiable campaniform sensilla, mechanosensory structures that encode deformation of the cuticle. Four of the neurons adapt rapidly to step deformations, the other four cells are slowly adapting and show a lower threshold sensitivity. A preparation has been developed for examining the dynamic properties of these sensory neurons in more detail. The campaniform dome is indented directly with noise stimuli using a microprobe that allows measurement of the force of indentation while simultaneously recording the impulse frequency of the neuron. The data is analysed by estimating the Wiener series kernels that describe the encoding process. This analysis will be useful in examining the role that these campaniform sensilla play in the flight behavior of the blowfly.

CORRECTIVE FLIGHT STEERING IN *LOCUSTA MIGRATORIA*: NEURAL PROCESSING AND FUNCTION OF COMPENSATORY HEAD MOVEMENTS. K. Hensler, Zoologisches Institut, Rheinsprung 9, 4051 Basel, Switzerland

Flying locusts detect involuntary deviations from course by exteroceptors on the head (eyes, ocelli, wind-sensitive hairs) and correct them by activity changes in thoracic muscles controlling movements of wings, legs and abdomen. During steering, compensatory head movements stabilize the retinal image. Information about deviations is transmitted from the brain to the thorax by descending movement detector neurons (DNs), which are mostly multimodal. Intracellular stimulation of single DNs in intact animals revealed that DN activity elicits both steering and compensatory head movements. Compensatory head movements reduce the visual (and wind) input caused by deviations. Thus, information about head movements/position must feed into the neural system underlying steering. It is shown that this convergence takes place at the level of DNs. In several DNs extero- and proprioceptive inputs are mixed in a complex manner. Generally the reduction of exteroceptive information by the compensatory head movement is replaced by input from neck proprioceptors. In single DNs this reduces, balances, or enhances the response compared to the same experiments with immobilized head. However, the summed response of all DNs, as expressed by steering reactions of wing muscles, is reduced. This is in accordance with behavioral data (D. Robert, in prep.): while fixating a visual target under closed loop conditions, deviations from the straight course are larger when the head is immobilized than when the head moves. Thus, besides stabilization of the retinal image, compensatory head movements minimize overshooting steering reactions by modulating DNs via neck proprioceptors.

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THE GENERATION OF AN AUTONOMOUS CENTRAL PATTERN IN THE TERMINAL GANGLION OF A CRICKET. R.Hustert, Fakultät für Biologie, Universität Konstanz, D-7750 Konstanz, FR Germany.

Neuronal networks in the terminal ganglion (TG) of orthopteran insects generate several independent motor rhythms. In females of the cricket *Acheta domestica* a specific ventilatory rhythm drives the alternating contraction of a pair of sternal muscles which attach to the anterior part of the genital chamber (GC). The movements of the GC compress large lateral tracheae and pump their local volume of gas into the interior ipsilateral tracheae of the ovipositor. The alternating expansions of the tracheae cause local hemolymph movements.

Each extrinsic GC muscle receives two excitatory motoneurons from the 7th neuromere of the TG with neuropile processes to the contralateral hemiganglion and the posterior neuromere. Coordinating interneurons determine the alternating pattern between left and right side even in the completely isolated TG. The rhythm is changed in hypoxic conditions and remains unaltered by mechanosensory afferents.

THE LOCUST FLIGHT MOTOR PROGRAMME: STUDIES OF A CENTRAL PROGRAMME AND ITS ONTOGENY. W. Kutsch* and P.A. Stevenson, Fakultät für Biologie, Universität, 7750 Konstanz, F.R.G.

The locust flight motor programme has been studied under various conditions (tethered intact, different degrees of deafferentation, isolation of parts of the CNS). Wind stimulation or octopamine (ionophoresis or bath application) have been used for pattern generation. All motor outputs had certain parameters in common to a flight of tethered intact locusts. We, therefore, claim that at least within the metathoracic ganglion a neuronal circuitry is present which can produce all major aspects of the flight motor programme.

By use of octopamine the ontogeny of this programme has been tested. It becomes apparent that in all larval instars a motor output can be elicited reflecting typical parameters of flight. Apparently, the basic neuronal circuitry is completed with embryogenesis, although this motor programme is of relevance only for the adult stage.

NEURONAL CONTROL OF RESPIRATION IN THE QUIESCENT AND FLYING LOCUST. J.M. Ramirez*, K.G. Pearson, Department of Physiology, University of Alberta, Edmonton, Alberta, Canada, T6G 2H7.

It has been well established that the respiratory rate in locusts increases at the onset of flight, but nothing is known about the neuronal processes underlying this change in respiratory activity. A necessary prerequisite for an understanding of the neural mechanisms is knowledge of the organization and properties of interneurons in the respiratory system. We have identified 10 rhythmically active neurons that reset the respiratory rhythm when injected with current pulses. These neurons are located in abdominal and thoracic ganglia as well as the suboesophageal ganglion (SOG). The activity of all respiratory neurons is changed at flight onset. Some inspiratory neurons which speed the rhythm are excited and one neuron is modulated with the flight rhythm. The mechanisms causing these changes may include descending neurons involved in flight initiation. Consistent with this proposal is that tonically active neurons in the SOG that disinhibit the flight system at flight onset also disinhibit the respiratory system and so increase the respiratory rate.

TEMPERATURE EFFECTS ON THE WING BEAT FREQUENCY IN BEETLES (COLEOPTERA). J. J. Oertli, Department of Entomology, Cook College, Rutgers University, New Brunswick, NJ, 90903, U.S.A.

Wing beat frequencies ($\bar{n}$) and thoracic temperatures (T_{th}) of 13 species of free flying beetles ranging from 3 mg to 200 mg were measured at different air temperatures. The effect of T_{th} on the frequency varied greatly among different species. Q_{10} 's ranged from 1.0 to 1.4 and were independent of taxonomic affinity and morphological parameters (wing area, length, and mass, and body length and mass). However, a strong correlation with the average $\bar{n}$ was observed. Because of the variable and low Q_{10} values, the effect of T_{th} on $\bar{n}$ is unlikely to be a result of muscle temperature dependence. Additionally lack of correlation with morphological parameters eliminates these as causal agents. As a consequence, these data suggest that observed changes in frequency are a result of temperature dependent changes in resonance properties of the thorax.

ON THE NEURAL BASIS OF ACTIVE MOVEMENTS OF STICK INSECTS. U. Bässler, Fachbereich Biologie der Universität, D-6750 Kaiserslautern, F.R.G.

Stretching the femoral chordotonal organ produces a strong resistance reflex in the inactive stick insect. In the active animal the same stimulus releases a complicated response which is called the active reaction. The active reaction controls the velocity of active flexion movements and the endpoints of flexion and extension. The network producing the active reaction is a subunit of the walking-pattern generator, but it is also involved in the control of searching-movements. Apparently, the neural generators for the different kinds of rhythmic leg movements use the same set of subunits, only the coordination between them is different.

The active reaction is produced by certain spiking interneurons in the ventral anterior midline of the thoracic ganglia. They are functionally coupled only in the active animal.

NEUROPHYSIOLOGICAL EVENTS WHICH CHARACTERIZE RELEASE OF THE PROTHORACICOTROPIC HORMONE DURING LARVAL DEVELOPMENT OF THE TOBACCO HORNWORM, *MANDUCA* *SEXTA*. K. Tomicka* and W.E. Bollenbacher, Department of Biology, Coker Hall, The University of North Carolina, Chapel Hill, NC 27599-3280, USA.

The initiation of larval molting in the tobacco hornworm, *Manduca sexta*, involves an endocrine cascade which begins with the release of the cerebral prothoracicotropic hormone (PTTH) from the retrocerebral corpora allata (CA). During the 4th larval instar when the gated release of PTTH occurs, the *in situ* electrical activity of the nervi corporis cardiacum (NCC I+II), the paired nerve trunks for brain (Br) innervation of the corpora cardiaca (CC) and CA, undergoes a distinct change in firing pattern. The initial change in pattern, from a steady firing, was a brief intense burst of relatively large units. A short period of completely suppressed activity (3-10 min) followed, after which activity resumed in the form of bursts of several kinds of units previously not active. Depending upon the preparation, this event was either long-lasting or short in duration. PTTH activity released from the CA, detected with an *in vitro* assay for the hormone, occurred only during the period of unique, long-lasting bursts, suggesting this bursting pattern was a neurophysiological event associated with PTTH release. This bursting pattern occurred at a particular time of day during the scotophase, and was expressed by the Br-CC-CA both *in situ* and *in vitro*. The complexity of the bursting pattern around the time of PTTH release suggests that a variety of cell types may be involved in a coordinated, transient inhibition of electrical activity of the NCC I+II that is followed by a selective disinhibition of a specific set of cerebral neurons culminating in PTTH release.

DISTRIBUTION OF SEROTONIN THROUGHOUT THE NERVOUS SYSTEM OF *RHODNIUS PROLIXUS* STAL: EVIDENCE FOR ITS RELEASE DURING FEEDING. I. Orchard*, A.B. Lange and F.M. Barrett, Department of Zoology, University of Toronto, Toronto, Ontario, Canada M5S 1A1.

The distribution of serotonin in *Rhodnius prolixus* has been studied using both immunohistochemistry and electrochemical detection. Serotonin and serotonin-like immunoreactive neurons are distributed throughout the CNS. Several of the peripheral nerves are covered in a plexus of immunoreactive processes. These processes form neurohaemal areas in which serotonin is present and from which it can be released in a calcium-dependent manner.

Serotonin-like immunoreactive processes extend along the full length of the abdominal nerves and project onto the dorsal and ventral epidermis which is covered by an extensive plexus of such processes.

Serotonin concentration is low in the haemolymph of unfed fifth instar larvae but increases 16-fold within 5 min of the onset of gorging. Correspondingly, the intense serotonin-like immunoreactive staining of processes on the dorsal integument of unfed insects, is almost undetectable in insects tested 15 min after the onset of gorging.

These findings indicate that serotonin acts both centrally and peripherally in *Rhodnius* and that it may be particularly important in the integration of feeding activity.

PURIFICATION AND PROPERTIES OF A β -D-GLUCOSIDASE (LINAMARASE) FROM THE HEMOLYMPH OF *ZYGAENA TRIFOLII* (LEPIDOPTERA; ZYGAEINAE). S. Franzl*, A. Nahrstedt, Institut für Pharmazeutische Biologie und Phytochemie, Hittorfstr. 56, 4400 Münster, F.R.G.

A β -glucosidase (linamarase) was purified from the larvae of *Z. trifolii*. Nearly all linamarase activity is stored in the hemolymph. The final enzyme preparation was found to be homogenous on polyacrylamide gel electrophoresis. The molecular weight of the enzyme was determined to be 138 kilodaltons by Sephacryl S-200 gel filtration. The enzyme showed a pH optimum of 4.8 with linamarin and a broad pH optimum between 3.5 and 6.5 for p-nitrophenyl β -D-glucoside.

The β -glucosidase isolated from the hemolymph of *Z. trifolii* shows a high specificity for its endogenous substrates linamarin and lotaustralin. These two cyanogenic glucosides also occur in the hemolymph of the larvae. Among the other natural and artificial substrates tested, only prunasin was hydrolyzed by the enzyme, whereas amygdalin, linustatin, salicin, cellobiose and trehalose were not metabolized.

The role of the linamarase as a cyanide-liberating enzyme in the defense biology of the larva is discussed.

PROTEIN INHIBITORS FROM THE INTEGUMENT AND HEMOLYMPH OF THE SILKWORM, *BOMBYX MORI* (LEPIDOPTERA: BOMBYCIDAE) AGAINST FUNGAL PROTEASES. M. Eguchi*, M. Yamashita and S. Yoshida, Department of Applied Biology, Kyoto Institute of Technology, Matsugasaki, Kyoto 606, Japan.

The inhibitory activity against proteases from *Beauveria bassiana* and *Aspergillus melleus* was found to be high in the hemolymph and integument of the silkworm. By polyacrylamide gel electrophoresis, intense inhibitor bands (D, F) and faint bands (A, E) were detected against *Aspergillus* protease in the hemolymph, whereas the band D was undiscernible in the integument. DEAE-Sep hacel column chromatography showed inhibitor fractions in the hemolymph corresponding electrophoretic bands and a main peak, F in the integument was seen for proteases from *A. melleus* and *B. bassiana*.

Above results suggest that the inhibitor F is most important in defensive function against invading fungi. The partially purified F was characterized and this inhibitor was found to inhibit the germination and tube development of conidia of *Beauveria bassiana* and *Beauveria brongniartii*.

ANCILLARY ANTIOXIDANT ENZYME ACTIVITIES AND INSECT RESISTANCE TO PLANT PRO-OXIDANTS. R.S. Pardini, J.L. Wang, R.P. Pardini, C. Capps and C.A. Pritsos, Department of Biochemistry, University of Nevada, Reno, NV 89557

Endogenous activities of total diaphorase (TD), DT-diaphorase (DT-D), glutathione transferase (GT) and aldehyde dehydrogenase (ADH) were determined in 5th instar larvae from *Trichoplusia ni*, *Spodoptera eridania* and *Papilio polyxenes* representing insect species naturally exposed to low, intermittent, and high levels of plant pro-oxidants respectively. *T. ni* possessed the highest activity of TD whereas DT-D was generally higher in *P. polyxenes*. *T. ni* and *S. eridania* possessed GT activities of 0.1-0.2 μ moles/min-mg prot and *P. polyxenes* possessed GT activities of 1.3-2.4 μ moles/min-mg prot. No differences were observed in ADH activities between the various insects, suggesting that endogenous GT and possibly DT-D are important for insect resistance to allelochemical pro-oxidants. The antioxidant enzymes superoxide dismutase and glutathione reductase were previously shown to parallel resistance to pro-oxidant allelochemicals in these same insects. The known aromatic hydroperoxide transferase portion of GT may be of particular importance in detoxifying organic hydroperoxides since all three insects were reported to be deficient in glutathione peroxidase activity. This work was supported by USDA Competitive grant 86-CRGR-1-2038.

THE EFFECT OF NEUROTOXIC INSECTICIDES ON THE cAMP LEVEL IN HOUSEFLY BRAINS AND THE MUTUAL SYNERGISM OF FORMAMIDINES WITH DDT AND DELTAMETHRIN. J. T. Chang* and Y. Ma, Department of Biology, Peking University, Beijing, China.

Among 20 neurotoxic insecticides investigated, only formamidines(4), DDT and pyrethroids (4) result in increase of cAMP in housefly brains. The time course of chlordimeform shows two rises of cAMP at 0.5 hr and 4 hr respectively, due to the action of chlordimeform and demethylchlordimeform. DDT and deltamethrin also result in two rises of cAMP at 1.0 and 6th hr. The first rise is due to the production of tyramine and octopamine under the stress of the insecticides. The second rise is probably due to the inhibition of cAMP-phosphodiesterase by the insecticides. Chlordimeform synergizes the action of DDT and deltamethrin by preventing the degradation of the two biogenic amines through the inhibition of monoamine oxidase. DDT and deltamethrin synergizes the action of chlordimeform by increasing cAMP.

PLANT GROWTH HORMONES: THEIR REGULATORY SIGNIFICANCE IN THE BIOLOGY OF LOCUSTS AND GRASSHOPPERS. S.N. Visscher* and S. Geldiay, Department of Entomology, Montana State University, Bozeman, Montana, U.S.A. and Department of Zoology, Ege University, Bornova, Izmir, Turkey.

Locust and grasshopper species fed different single species of host plants may exhibit significantly different rates of growth and reproductive success for yet unknown reasons. Experiments were conducted in which the range-land grasshopper *Aulocara ellioti* and the African migratory locust *Locusta migratoria* were fed a defined diet devoid of unrefined plant material to which plant growth hormones were added. Highly significant dose-related differences in growth and reproduction were observed. Because these plant hormones vary seasonally and aseasonally in kind and concentration with changes in environmental conditions, it is suggested that in host plants they may help insects that ingest them to integrate their life cycles to sequential changes in their hosts. The molecular diversity of the naturally occurring plant growth hormones may have been important in establishing the relationships between insect and plant taxa, since ecdysone and juvenile hormone are derived from the same metabolic pathway as several of the plant hormones. This insight may have value in management of these important phytophagous insect pests.

DISCOVERY OF AN ANTIJUVENILE HORMONE IN THE PLANT *CHRYSANTHEMUM CORONARIUM*.

William S. Bowers* and Manuel Aregullin, Department of Entomology, The University of Arizona, Tucson, AZ 85721, USA.

The defensive chemistry of plants has often provided the prototypic chemistry useful in medicine and in plant and animal protection. Insect hormone mimics and antihormones have been discovered among plant secondary chemicals. The antijuvvenile hormonal chemicals, known as the precocenes, induce precocious metamorphosis and sterilization of a variety of sensitive insect species and have been well characterized. We have discovered a compound in the plant *Chrysanthemum coronarium* (Compositae) which, although chemically unrelated to the precocenes, possesses antijuvvenile hormone activity against several insect species. Chemical characterization studies confirm the structure of the antihormone as a polyacetylenic sulfoxide. The discovery among the polyacetylenes of an antijuvvenile hormone adds a new dimension of activity to this important class of biologically active natural products.

PH 70-23: A NEW CHITIN DEPOSITION INHIBITOR WITH ACARICIDAL AND INSECTICIDAL ACTIVITIES. A.C. Grosscurt, Duphar B.V., Crop Protection Division, P.O. Box 4, 1243 ZG 's-Graveland, The Netherlands.

PH 70-23 is a new benzoylphenylurea interfering with chitin deposition. The compound combines high acaricidal and insecticidal activities. Both tetranychid and eriophyid mites are susceptible. The biological activity of PH 70-23 consists of a larvicidal and an ovicidal component. The latter acts by direct contact as well as transovarially, following treatment of female adults. The compound lacks adulticidal activity. Development of PH 70-23 is especially aimed at its acaricidal activity. In laboratory experiments, the effects of a number of separate factors, a.o. temperature and host plant, on biological activity have been studied. The results, together with the intrinsic biological properties of PH 70-23, partly explain the observed dependence of field dosages on application time, target species and crop.

INSECT FEEDING AND DEVELOPMENT CONTROL BY CONSTITUENTS OF *MELIA AZEDARACH* AND *AZADIRACHTA INDICA*

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From *Melia azedarach* and *Azadirachta indica* (neem tree) we have isolated several novel highly oxidized tetranortriterpenoids related to azadirachtin which impair insect feeding and/or development. On the basis of the structure determination of these compounds by NMR and an extensive reinvestigation of the NMR spectra of azadirachtin itself we determined for the first time the correct structure for azadirachtin.¹⁾ In addition some new salannin, nimbin, and vilasinin derivatives were obtained which also show biological activity. The results of the antifeeding and IGR tests will be reported. Structure-activity relationships will also be discussed.

- 1) W. Kraus, M. Bokel, A. Klenk, and H. Pöhl, *Tetrahedron Lett.* **26**, 6453 (1985); W. Kraus, M. Bokel, A. Bruhn, R. Cramer, I. Klaiber, A. Klenk, G. Nagl, H. Pöhl, H. Sadlo, and B. Vogler, *Tetrahedron* **43**, 2817 (1987).

BIOSYNTHETIC PATHWAY OF BOMBYKOL, AND PHEROMONE BIOSYNTHESIS ACTIVATING NEUROPEPTIDE HORMONE (PBAN) OF THE SILKWORM MOTH (*BOMBYX MOLI* L.)
Tetsu ANDO, Dept. of Plant Protection, Tokyo University of Agriculture and Technology, Fuchu, Tokyo 183, Japan

For investigation of the biosynthetic pathway of bombykol, some ¹⁴C-labelled compounds were applied to the pheromone glands. [1-¹⁴C](Z)-11-Hexadecenoic acid changed more easily to bombykol than [1-¹⁴C]hexadecanoic acid, while [1-¹⁴C](E)-11-hexadecenoic acid and [1-¹⁴C]hexadecan-1-ol were scarcely incorporated into the pheromone. This result confirmed the biosynthetic pathway via (Z)-11-hexadecenoate and (10E,12Z)-10,12-hexadecadienoate. Some [1-¹⁴C](Z)-11-hexadecan-1-ol was changed to bombykol, suggesting that the alcohol was oxidized to (Z)-11-hexadecenoic acid and this acid was taken into the biosynthetic pathway.

The pheromone biosynthesis of *B. mori* was also controlled by a peptide hormone, named PBAN (Raina et al., 1986), as that of *Heliothis zea*. Heads of about 20,000 moths were homogenized in acetone and divided into some fractions. The decapitated female injected with the fraction, which was extracted with 80% EtOH, produced bombykol. When this fraction was treated with pronase P or trypsin, its activity was completely destroyed. The molecular weight of PBAN from *B. mori* was tentatively estimated to be 3000-6000 Daltons from the elution profile on a Sephadex G-50 column.

BIOSYNTHESIS OF PHEROMONES BY SELECTED SPECIES OF GRAIN AND BARK BEETLES. D. Vanderwel*, A.C. Oehlschlager, S.M. Singh, S. Ramaswamy, T. Cutforth, H.D. Pierce, Jr., A.M. Pierce and J.H. Borden. Department of Chemistry, Simon Fraser University, Burnaby, B.C., Canada. V5A-1S6.

Coleopteran pheromone biosynthesis is being studied in our laboratory using stable-isotope labelled precursors. Macrolide aggregation pheromone biosynthesis in the grain beetle, *Cryptolestes ferrugineus*, was found to utilize both dietary precursors and those synthesized *de novo*. The relative contribution of each pathway to overall pheromone biosynthesis was examined. It was also shown that when insects were allowed to feed on oats coated with 11-deutero-11-hydroxy-3-dodecenoic acid, the corresponding lactone pheromone produced was enriched with deuterium. The direction of cyclization was studied using deuterated precursor that was also labelled with ¹⁸O at the hydroxyl oxygen, and checking for retention of ¹⁸O in the deuterated pheromone produced.

The second area of investigation is the biosynthesis of the bicyclic ketal pheromone *exo*-brevicomin by bark beetles. When *Dendroctonus ponderosae* was exposed to 4-deutero-2-non-6-ene-2-one, the *exo*-brevicomin produced was enriched for deuterium. Additional labelling studies have yielded incisive information on the mechanism of cyclic ketal biosynthesis.

TARSAL CHEMORECEPTORS IN *HELIOTHIS VIRESCENS*: RESPONSES TO SUGARS, SALTS AND PLANT EXTRACTS. S. B. Ramaswamy* and F. E. Hanson, Dept. of Entomology, MSU, Mississippi State, MS 39762 and Dept. of Biological Sciences, UMBC, Catonsville, MD 21228.

The ventral tarsal surface of *Heliothis virescens* has 3 types of sensilla, two of which are contact chemosensilla and one mechanosensilla. Both types of chemosensilla exhibit dose-dependent responses to sucrose, NaCl and KCl. Two cells respond to NaCl with different spike amplitudes. Frequency of the small salt spike increases after ca. 1 sec. of stimulation with higher concentrations of NaCl. In contrast, only one cell responds to KCl. Only one cell also responds to sucrose with mostly monopolar positive response that becomes bipolar at higher concentrations. Maximal response occurs at 0.05 M sucrose and, interestingly, 0.02 M sucrose elicits proboscis extension response on tarsal contact in 50% of the individuals tested. Response to sucrose adapts within 100 msec and disadapts completely within 15 sec. Both types of sensilla respond to methanolic extracts of hosts and non-host with differences in the pattern of response to extracts of tobacco, cotton and ground cherry.

HOST ODOUR PERCEPTION IN THE COLORADO POTATO BEETLE. R. De Jong* and J.H. Visser. Department of Entomology, Wageningen Agricultural University, P.O. Box 8031, 6700 EH Wageningen, The Netherlands.

The composition of the so-called 'green odour' which forms a significant part of all leaf odour blends, is important in the Colorado potato beetles' recognition of the odour of its host, potato. Response spectra derived from recordings of antennal olfactory receptors of the beetle to stimulation with 5 general green odour components, overlap in their sensitivity to individual stimuli but show gradual differences in their degree of specialization. Response levels of the receptors depend on either the presence of certain compounds (in generalist receptors), or on the ratio of these compounds (in specialist receptors). Olfactory information, therefore, is thought to be analyzed by separating information about the quality and the quantity of a stimulus. The contrast between responses of quality- and quantity-sensitive neurones is enlarged in the deutocerebrum. A combination of information derived from these two information channels could code for the presence of potato plant odour.

EFFECTS OF REDUCING AGENT, GLUTATHIONE ON THE METABOLIC STATUS OF SCHIZODACTYLUS MONOSTROSUS DURING SENESCENCE WITH EMPHASIS ON TROPHIC METABOLISM
D.K.Choudhuri, Department of Zoology, Burdwan University, Burdwan 713104, India.

In insect gerontology biochemical studies of fat body and haemolymph have assumed much importance for their ability to reflect physiological state of an insect in proper perspective. This study incorporates the results of an investigation made on the biochemical changes during ageing in *S. monstrosus* in experimental (treated with glutathione) and control conditions. The parameters studied include pH & sp. gravity of haemolymph, total & differential haemocyte counts, trehalose, total sugar, total protein, free amino acids, total lipid, free fatty acids, and enzymes like catalase, peroxidase, polyphenol oxidase, trehalase, alkaline and acid phosphatases, general esterase, glutamate oxaloacetate transaminase & glutamate pyruvate transaminase in haemolymph and fat body of insects of different age. The results show that senescence is a time dependent universal process though, yet it produces with advancement of age certain physiological changes which play key role in diminishing the life span. A total metabolic shift from reductive to oxidative stage augmenting the process of ageing is conspicuous.

EFFECT OF TEMPERATURE ON EGG INCUBATION AND DEVELOPMENT IN AN AQUATIC INSECT LACCOTREPES GRISEUS GUERIN (HEMIPTERA : NEPIDAE) : A MATHEMATICAL APPROACH. E. Jayakumar* and S. Mathavan, School of Biological Sciences, Madurai Kamaraj University Madurai 625 021 India.

A comprehensive study on the influence of constant incubation temperature on incubation duration, volume change, water absorption and process of successful hatching has been studied in an aquatic bug Laccotrepes griseus. The duration of embryonic development is inversely related to temperature. Incubation period was 22 days at 20°C; it was 11, 9 and 7 days at 25, 30 and 35°C, respectively. Maximum hatchability of 96% was observed at 25°C and the minimum of 82% at 20°C. Based on Trottier's formula (1971) 14.92°C is considered to be the threshold temperature for embryonic development. The data obtained in the present study have been subjected to mathematical models. The number of degree-days for hatching varied from 115 at 20°C to 135 at 35°C. The changes in wet and dry weights, water content and egg volume were studied as functions of developmental period and incubation temperature.

#111

EVALUATION OF THE EFFECTS OF GAMMA IRRADIATION ON THE DEVELOPMENT OF THE REPRODUCTIVE SYSTEM OF ADULT FEMALES OF *PHTHORIMIA OPERCULELLA*, ZELL., Kamelia A. Abdel-Salam, Atomic Energy Authority, Nuclear Research Center, Radiobiology Dept., Abo-Zaabal 13759, Egypt.

Laboratory studies were carried out in Egypt to evaluate the effect of different doses of gamma radiation from radioactive cobalt (^{60}Co) on reproductive system of adult females of *Phthorimia operculella* treated as 5- and 10-day old larvae.

The adult females which developed from treated larvae exhibited different degrees of malformation in their reproductive systems. The degree of deformity and inhibition in the reproductive system depends upon the used dose and age of larvae at time of treatment, started with a slight damage and continued accelerated obviously in the main parts of the system. The 10-day old larvae were more radiosensitive than 5-day old larvae i.e., the ovaries were in a poorly developed condition, but the associated structures were normal. When these adult females were paired with untreated males the mating ability was slightly affected. The production of females with disrupted ovarian development and normal mating ability indicated that the application of the sterile-insects-release technique for population suppression of this species seemed to be feasible.

#112

SCLEROTIZATION OF INSECT CUTICLE IN A CELL FREE SYSTEM. O.P. Agrawal* and K. Scheller, Zoologisches Institut der Universität Würzburg, Röntgenring-10, D-8700, Würzburg, FRG. * School of Studies in Zoology, Jiawaji University, Gwalior 474011, India.

The incubation of deproteinized larval cuticle (chitin flake) of *Calliphora vicina* with purified larval serum protein, calliphorin or the larval haemolymph resulted in chitin-protein complex formation. The oxidation of the sclerotizing agent N-B-alonyldopamine (NBAD) by the enzyme tyrosinase results in the formation of insoluble polymer, the quinone. When this oxidation was performed in the presence of deproteinized cuticle, the NBAD-quinone was incorporated into the cuticle. The presence of protein (calliphorin) in the cuticle resulted in apparently a higher degree of incorporation.

Thus the insect cuticle can be sclerotized in a cell free system and the protein(s) (Calliphorin for e.g.) participate in the process.

#113

ON THE LARVAL SERUM PROTEIN OF THE HOUSEFLY *MUSCA DOMESTICA* L. O.P. Agrawal, R. Sardana and J. Bahadur*, School of Studies in Zoology, Jiawaji University, Gwalior 474011, India.

The analysis of haemolymph and fat body samples during late larval and early pupal development of *M. domestica* by sodium dodecyl sulphate polyacrylamide gel electrophoresis (SDS PAGE) has revealed that the larval serum protein (LSP) is the most prominent haemolymph protein synthesized and released from the fat body during feeding third instar larva. During pupariation it is reabsorbed in the fat body as storage protein to be used in future development. The protein is a hexamer with molecular weight of about 500,000, whose subunits resolve on SDS PAGE in a typical double band at 85000 molecular weight.

The LSP was purified from larval haemolymph on acrylamide gel slab. The larval haemolymph and purified LSP showed slight immune response to the purified antibodies raised against pure LSP of *Calliphora vicina*. Selective staining of purified protein on agarose gel showed that it is a lipo-glyco-protein.

#114

HEMAGGLUTININATING ACTIVITY IN THE HEMOLYMPH OF *BOMBYX MORI*. Kazuhito Amanai*, Sho Sakurai, Tetuya Ohtaki, Department of Biology, Faculty of Science, Kanazawa 920, Japan

Hemagglutinating activity in the hemolymph of the silkworm, *Bombyx mori*, was measured through the 4th instar to adult stage using sheep red blood cells treated with trypsin and glutaraldehyde. The activity was relatively high at the end of the 4th instar and the time of gut purge. The change in activity seemed to be under the control of ecdysteroid, at least, during the 5th instar. This indicated an important role of hemagglutinin in the course of morphogenesis underlying metamorphosis in insects.

Protein with hemagglutinating activity was purified by precipitation with 30% saturated ammonium sulfate, column chromatography of Sephacryl S-300, DEAE-Sephacel and affinity chromatography using glucuronic acid as ligand. Biochemical analysis on the purified hemagglutinin indicated that it is approximately 330Kd protein composed of 3 different subunits with molecular weight of about 80000 for each.

#115

CHARACTERIZATION OF MIDGUT ALKALINE PHOSPHATASES FROM THE SILKWORM, *BOMBYX MORI* (LEPIDOPTERA: BOMBYCIDAE). M. Azuma*, N. Okada, H. Yamamoto and M. Eguchi, Department of Applied Biology, Kyoto Institute of Technology, Matsugasaki, Sakyo, Kyoto 606, Japan.

Silkworm midgut possesses two alkaline phosphatase (ALP) isozymes, membrane-bound (m-ALP) and soluble (s-ALP) forms, that are controlled by two separate genes on the same chromosome. We have purified and characterized both ALPs in order to elucidate the possible functions of midgut ALPs and relationship between two isozymes. Two forms were found to be similar Mr=68,000 in gel permeation chromatography and a single subunit as a monomer in denaturing SDS-PAGE with Mr=58,000. They showed similar amino acid compositions and pI (4.8). The pH optima of both ALPs were shown to lie at 10.8 (m-ALP) and 9.7 (s-ALP), and m-ALP is extremely stable in pH 10-12 which accords with the physiological milieu in silkworm midgut lumen.

The antibody raised against purified m-ALP recognized m-ALP but not purified s-ALP. Rocket-immunoassay showed that m-ALP distributed in similar levels along the length of midgut except the most anterior portion. 70% of s-ALP activity existed in the last one-third of midgut. Immunoassay of s-ALP are in progress. These results suggest that m-ALP and s-ALP are distinct isozymes and undertake different roles.

#116

NEURONAL CONTROL OF THE POSITION OF HEAD AND ABDOMEN IN STEERING LOCUSTS DURING FLIGHT.

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Steering maneuvers in flying locusts can be elicited by movements of an artificial horizon with integrated wind jet. The animals achieve this by changing the angle of pronation of the fore wings, bending the abdomen and hind legs towards the appropriate direction, and turning the head. Informations about changes in the environment, eliciting steering responses are perceived by the complex eyes, ocelli, and wind hairs, and transmitted to the target motoneurons in the thorax via descending interneurons (DNs, Rowell & Reichert 1986, Hensler 1987). A single DN can activate both flight and neck motoneurons (NMNs). In the prothoracic ganglion, DNs running in the lateral dorsal tract make short latency excitatory and indirect inhibitory connections with NMNs. Some of these NMNs are differentially co-activated to control the amplitude of the head movements. At least one type of DN is tonically excited by horizon deviations and provides a strong input to these NMNs. NMNs in the mesothoracic ganglion get long latency visual input and their activity is modulated with flight rhythm. Motoneurons of the abdominal longitudinal muscles of both sides of the abdomen are also co-activated with different intensities to produce bending of the abdomen towards the appropriate direction.

Flight and steering behavior is somewhat different when simulating "natural" flight conditions with a flow-field device. Head turning responses are increased when locusts are stimulated in an air stream together with the flow-field pattern and often flight can be initiated. During flight, flow-field often increases the wing beat frequency. The complex flow-field stimulus leads to a general increase of activity or to an enhancement of the horizon response in specific DNs of the lateral dorsal tract.

Supported by the Swiss National Fond.

#117

ULTRASTRUCTURAL LOCALIZATION OF PHENOLOXIDASES IN CUTICLE AND HAEMOPOIETIC TISSUE OF *LUCILIA CUPRINA*. F. Michael Barrett and Keith C. Binnington, Department of Zoology, University of Toronto, Toronto, Canada M5S 1A1 and Division of Entomology, CSIRO, Canberra 2601, Australia.

The ultrastructural localization of two types of biochemically characterized phenoloxidase activity is described in larval cuticle of the sheep blowfly, *Lucilia cuprina*. Tyrosinase (enzyme A) is seen in epicuticular filaments and procuticle. Activity in the latter can only be detected after a presumed process of activation takes place in damaged cuticle. The dopamine reaction or hot water-induced melanization also reveal tyrosinase (not necessarily the same enzyme as in the cuticle) in haemopoietic tissue located subdermally and associated, as well, with the dorsal vessel.

Diaminobenzidine staining, which can be used to identify the laccase, enzyme B, in electrophoretic gels, is adapted here to ultrastructural cytochemistry to demonstrate this enzyme activity in the inner epicuticle of late wandering third instar larvae just at the time of pupariation. This staining was not seen in younger wandering stage larvae, a finding matched by biochemical assays on intact cuticle and consistent with the proposed deposition of enzyme B in the cuticle to act in sclerotization of the puparium.

#118

PROCTOLINERGIC TRANSMISSION AT THE OPENER MUSCLES OF THE OVIPOSITOR OF *LOCUSTA MIGRATORIA*. Jim H. Belanger and Ian Orchard, Dept. Zool., Univ. Toronto, Toronto, ON, Canada.

The opener muscles of the locust ovipositor are large skeletal muscles whose main use is in digging the female's oviposition hole. Several lines of evidence indicate a role for the pentapeptide proctolin (PRO) in the control of these muscles. Using the locust oviducal muscles as a bioassay, extracts of opener muscle are found to contain PRO-like bioactivity (PLB). PLB is abolished if the extract is incubated with anti-PRO antibody. PLB co-elutes with ³H-PRO after RP-HPLC on each of two solvent systems.

Opener muscles are sensitive to PRO. Bath-applied PRO causes a dose-dependent contraction, with a maximum tension greater than 50% of that produced by high-potassium depolarization. 10⁻⁷ M PRO produces maximal tension, but has no effect on muscle fibre resting potential or input resistance. It does increase the frequency, and possibly the amplitude distribution, of miniature endplate potentials.

The above results suggest a dual action of PRO on the opener muscle. There is a direct effect on the muscle fibres to cause contraction, and a presynaptic effect to increase the probability of transmitter release.

#119

FARNESOIC ACID AND METHYL 12,12,12-TRIFLUOROFARNESOATE STIMULATE *IN VITRO* PRODUCTION OF JH III IN *BLATTELLA GERMANICA*. X. Bellés, J. Casas*, A. Messegue and M.D. Piulachs. Dpt. of Biological Organic Chemistry, J. Girona, 18. 08034-Barcelona. SPAIN.

We have reported that CA of *B. germanica* adult females produce JH III and that the release dynamics can be followed by using the *in vitro* radiochemical assay developed by Pratt and Tobe (X. Bellés et al., *Insect Biochem.*, 1987, 17, 1007). In this communication results on the study of the *in vitro* incubations of CA-CC complexes from newly emerged females (day 0), females at the highest production age (day 6) and females carrying the ootheca (day 8) in the presence of title compounds are reported. Farnesoic acid induced remarkable stimulation of JH III production in all ages, showing an approximate 3:3:12 ratio in respect to standard values. Additionally, while stimulatory effects were reversible for CA from females of days 0 and 8, in the case of glands from fully active females, stimulation persisted in the post treatment period, thus suggesting an intraglandular accumulation of either biosynthetic precursors or the hormone itself. Measure of intraglandular levels of methyl farnesoate and JH III have confirmed this hypothesis. Concerning the fluorinated ester, it also showed a stimulating effect on JH III production. Quantitatively, the activation was lower than that attained by farnesoic acid at equal concentrations (10⁻⁵M), particularly with CA from day 6 specimens. Assays carried out with several fluorinated compounds biometrically related to the ester have suggested that this compound exerts its action by a different mechanism than that operating in the case of farnesoic acid, which implies a *de novo* activation of JH III biosynthesis.

#120

PRECOCENE II INDUCED CHANGES IN MIDGUT EPITHELIAL CELLS OF THE CORN EARWORM, *HELIOTHIS ZEA*.

Bradley F. Binder* and William S. Bowers, Department of Entomology, University of Arizona, Tucson, Arizona, USA 85721.

Newly ecdysed fifth instar *Heliothis zea* larvae were fed *ad libitum* on artificial diet containing either 2 mM or 4 mM Precocene II for five days. Larval midguts were removed and prepared for both Transmission Electron Microscopy and Scanning Electron Microscopy.

Ultrastructural changes in the midgut epithelia indicate that cytotoxic damage is induced by Precocene II. In normal larvae numerous vacuoles and few intercellular canaliculi were present in midgut columnar cells whereas in the midguts of larvae exposed to Precocene II we observed no vacuoles and many intercellular canaliculi. The midgut goblet cells of larvae fed diet with 4 mM Precocene II were elongate with a narrow cavity compared to goblet cells of normal larvae or larvae fed diet containing 2 mM Precocene II.

We propose that the observed changes in the midgut epithelia result from the destructive alkylation of cell structures by Precocene II.

#121

TRANSLATION OF EPIDERMAL RNA FROM DIFFERENT ANATOMICAL REGIONS AND METAMORPHIC STAGES OF THE GIANT SILKMOTH *HYALOPHORA CECROPIA* USING RABBIT RETICULOCYTE AND WHEAT GERM. L.C. Binger* and J.H. Willis, Department of Entomology, University of Illinois, Urbana, IL 61801, U.S.A.

It has been shown that anatomical region rather than metamorphic stage is the major determinant of cuticular protein distribution in *Hyalophora cecropia*. To learn if the proteins found are the result of differential synthesis and secretion, rather than sclerotization, total RNA was isolated from different anatomical regions and metamorphic stages and translated, using both rabbit reticulocyte and wheat germ systems. The resulting proteins were visualized by electrophoresis followed by fluorography. Electrophoretic patterns of labelled translation products mixed with authentic cold standards showed clearly that the messages for the abundant cuticular proteins corresponded to the proteins found in each cuticular extract. The two systems yielded both quantitative and qualitative differences in translation products. This work established that the presence of the most abundant proteins in cuticular extracts correlates with the presence of their respective mRNAs, and that these messages are translated more efficiently in the wheat germ system. (Supported by NSF DCB 8607865)

#122

INSECTICIDAL AND PHYSIOLOGICAL ACTIVITY OF SYNTHETIC DELTA-PHILANTHOTOXIN AND ANALOGUES. G.A. Bradfish, Dow Chemical Co. 2800 Mitchell Dr., Walnut Creek, CA 94598.

The venom of the digger wasp, *Philanthus triangulum* contains several physiologically active components (Piek, et al., 1985, *Pestic. Sci.* 16:488). The most active component is δ -philanthotoxin (δ -PTX). In this study, synthetic δ -PTX and 15 analogues were evaluated for insecticidal activity against tobacco budworm (TBW, *Heliothis virescens*) larvae and for neuromuscular blocking activity against housefly *Musca domestica* skeletal muscle. Synthetic δ -PTX caused a reversible decrease in the amplitude of excitatory postsynaptic potentials recorded from housefly skeletal muscle at concentrations between 10 and 100 μ M with an I₅₀ of 60.4 μ M. Analogues of δ -PTX were tested to identify structural features which were necessary for neuromuscular blocking activity. In toxicity bioassays against TBW larvae, δ -PTX and analogues showed little or no toxicity. δ -PTX was found to be 10 fold less active at inhibiting neuromuscular transmission in TBW skeletal muscle than in housefly skeletal muscle. The low toxicity of δ -PTX to TBW larvae was attributed to the reversible blocking action and to a species related tolerance at the neuromuscular site of action.

#123

URIC ACID SEQUESTRATION IN SPECIFIC EPIDERMAL CELLS OF *MANDUCA SEXTA* LARVAE. J.S. Buckner, USDA-ARS, Metabolism & Radiation Research Laboratory, Fargo, ND, USA 58105.

Spatial distribution and temporal movement of uric acid in the epidermis of larval *Manduca sexta* was studied during the larval-pupal transformation. Uric acid in isolated epidermal tissue was higher (500 nmol/mg) in the dorso-lateral white stripes than in adjacent blue pigmented regions (30 nmol/mg). The pattern of distribution in the integument of fifth-instar larvae was confirmed by autoradiography following incorporation of ^{14}C -labeled uric acid. At 86 hr after fifth instar ecdysis, larvae fed diet containing ^{14}C -hypoxanthine for the first 48 hr contained significant levels of label mainly in the epidermal tissues. Within 24 hr about 80% of the label in the epidermal cells was either translocated to storage within fat body or excreted before the onset of wandering. HPLC analysis and reactivity with uricase were used to confirm that the stored labeled material within the epidermal and fat body tissues was uric acid. Ultrastructural studies revealed that the epidermal cells of white-pigmented integument contained an abundance of urate granules, whereas, the cells from blue regions contained few, if any, urate granules.

#124

EFFECTS OF METABOLIC SUBSTRATES ON THE TRANSEPITHELIAL POTENTIAL (TEP) ACROSS TOBACCO HORNWORM (*MANDUCA SEXTA*) MIDGUT. M.E. Chamberlin, Department of Zoological and Biomedical Sciences and College of Osteopathic Medicine, Ohio University, Athens OH 45701, U.S.A..

Ion transport studies on the midgut of the tobacco hornworm have been plagued by the rapid decline in TEP and short-circuit current during *in vitro* studies. The *in vitro* TEP across the posterior midgut of the tobacco hornworm can be maintained above 70 mV for at least four hours if bathed in a saline containing physiological levels of hemolymph inorganic and organic solutes (control saline). In contrast, when bathed in a substrate-free saline, the TEP quickly declines. The TEP can be completely restored by adding control saline or certain individual substrates. Citrate, succinate, malate, sucrose, fructose and octanoate produce the greatest stimulation while amino acids were less effective. This result corresponds with the pattern of substrate oxidation of midgut mitochondria. The mitochondria oxidize pyruvate, organic acids and fats while amino acids appear to be less important substrates (Chamberlin, J.Comp.Physiol. 157:643-649, 1987). Therefore, it appears that these added substrates are oxidized by midgut mitochondria to supply ATP for electrogenic processes.

#125

DETECTION OF GANGLIOSIDES IN INSECTS. J. T. Chang * and P. Gao, Department of Biology, Peking University, Beijing, China.

After a final and intensive investigation with 5 insects (0.2 – 10g of tissue for each), Warren (1963) reported that there was no sialic acid in insects. A general conclusion was since drawn that gangliosides were not present in insects. We used 4 insects (weight of tissue 120–1000g) and detected that insects do contain lipid bound sialic acids. The content ($\mu\text{g/g}$ wet wt) in *Musca domestica* is 0.86 ± 0.08 , in *Periplaneta americana*, 1.37 ± 0.10 , *Bombyx mori*, 1.47 ± 0.24 and *Apis mellifera*, 1.01 ± 0.32 . Using monodimensional TLC, six kinds of gangliosides are separated; they are: GM2, $16.93 \pm 0.10\%$, GM1, $14.41 \pm 0.19\%$, GD3, $13.95 \pm 1.11\%$, GD1a, $28.21 \pm 1.60\%$, GD1b, $10.25 \pm 0.93\%$, and GT1b, $16.24 \pm 1.14\%$. The average amount of ganglioside in insect brain is approximately 1/300 to 1/1000th of the amount in vertebrate brains.

#126

CORPUS ALLATUM (CA) AND CORPUS CARDIACUM (CC) REGULATION OF LONG HYALINE GLAND PROTEIN SYNTHESIS IN THE MALE GRASSHOPPER, *MELANOPLUS SANGUINIPES*. M.T. Cheeseman and C. Gillott, Department of Biology, University of Saskatchewan, Saskatoon, Saskatchewan, Canada S7N 0W0.

Rates of accumulation of, and radiolabel incorporation into, the major secretory product of the long hyaline gland, an Mr 72 000 glycoprotein LHPI, were used to examine the role of the CA and CC in the control of protein synthesis in the accessory reproductive gland of the male grasshopper, *Melanoplus sanguinipes*. Incorporation of [^{35}S]methionine into LHPI *in vitro* indicated that LHPI was an endogenous long hyaline gland protein, whose *in vivo* synthesis in allatectomized animals was stimulated by topical application of JHIII. This response was not dependent on the presence of the extrinsic lobe of the CC, the CC/brain complex or continued feeding and indicates a direct effect of JH on the gland. Increasingly severe CA manipulation caused progressive inhibition of LHPI accumulation and normal post-copulatory stimulation of LHPI accumulation was abolished by allatectomy. These results suggest that JH plays a physiological role in regulation of LHPI synthesis. CC effects were small in comparison to those of the CA; they were evident only in cardiacectomized animals that were allatectomized also and exerted over prolonged periods when the animals continued to feed.

#127

LONG-LASTING RECORDINGS OF OVIPOSITIONAL MOVEMENTS IN CONTROL AND OVARECTOMIZED ACHETA DOMESTICUS FEMALES: ACTION OF JH AND MATING.

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To continuously monitor ovipositional movements, a new actograph was devised: it was composed of a Iridium radioelement glued at the ventral tip of the ovipositor and which emitted γ rays; a scintillation probe, placed horizontally behind a slit in a lead wall just below the surface of the egg-laying substrate, detected these rays only when ♀ made ovipositional movements; a microcomputer stored and processed data.

In young virgin or mated ♀, the first ovipositional movements appeared on the 4th day after the imaginal moult (i.m.); at that time ovaries were immature but corpora allata were active. Mature virgin ♀ made ovipositional movements followed or not by the laying of a few eggs.

The removal of the ovaries before i.m. did not prevent the onset of ovipositional movements in 40% of both virgin and mated ♀. Prostaglandin (E2 α) injections induced ovipositional movements in all virgin ovariectomized ♀.

The removal of the corpora allata carried out 6 to 8 days before i.m. prevent the onset of movements. Injections of JH III restored the ovipositional movements previously abolished by allatectomy.

#128

BILIVERDIN BINDING PROTEINS IN THE BEAN BUG, *RIPTORTUS CLAVATUS* THUNBERG (HETEROPTERA: ALYDIDAE): PURIFICATION, CHARACTERIZATION, CHANGES OF CONTENT AND SYNTHESIS DURING DEVELOPMENT AND DIAPAUSE. Y. Chinzei^{*1}, T. Haruna¹ and H. Numata². ¹ Department of Medical Zoology, School of Medicine, Mie University, Edobashi, Tsu, Japan 514, ² Department of Zoology, Faculty of Science, Osaka City University, Sugimoto, Sumiyoshi, Osaka, Japan 558.

We purified cyanoprotein (CP) from *R. clavatus* eggs. CP had absorbance peaks specific to biliverdin. Molecular weight (MW) of CP was estimated as 320,000 to 335,000 daltons. CP is tetramer of single subunit (MW: 76,000) associated with 4 molecules of biliverdin. CP contains sugar moiety (13% neutral sugar – mainly mannose) but not lipid, and composed of high aromatic amino acids (17%). We detected four CP bands (CP 1,2,3 and 4) in the hemolymph by PAGE, which showed the same properties as egg CP in biochemical analysis. CP 1 is common to egg CP, but CP 2 to 4 are specific to hemolymph and show different mobility in PAGE, pI and immunological properties from egg CP. CP 1 to 4 are synthesized in the fat body and synthetic activity changes dynamically during the development and diapause. Each content of CP 1 to 4 in the hemolymph and whole body changes corresponding to the synthetic activity. We are studying on the regulation of CPs biosynthesis by juvenile hormone which controls the adult diapause.

#129

THE EFFECT OF TEMPERATURE ON THE DEVELOPMENT OF MALE AND FEMALE EMBRYOS OF THE APHID *MEGOURA VICIAE*. R. Crema and A.M. Bonvicini Pagliai, Department of Animal Biology, University of Modena, 41100, Modena, Italy.

In *Megoura viciae* Buckton, a temperature of 24°C is critical in that it prevents ovipara and male determination by long scotoperiods.

When embryos predetermined as males below the critical temperature are exposed to higher than critical temperatures, their viability becomes progressively lower. Female embryos are markedly less sensitive to high temperatures. A temperature of 27°C is fully lethal for male but not for female embryos.

A histological investigation was undertaken on virginoparae (bearing only female embryos) and on sexuparae (bearing male and female embryos) exposed to high temperatures in order to fully clarify this different thermal tolerance between sexes.

#130

CHARACTERIZATION OF THE Δ^{12} -DESATURASE IN THE HOUSE CRICKET, *ACHETA DOMESTICUS*. C. Cripps and M. de Renobales, Department of Biochemistry, University of Nevada, Reno, NV 89557

The biosynthesis of linoleic acid, an essential fatty acid for most animals but synthesized *de novo* in some insect species, has been investigated in microsomal preparations of 2-6 day old male house crickets, *A. domesticus*, using [$1-^{14}C$] oleoyl-CoA as substrate. HPLC analysis of lipid extracts from microsomal preparations indicated that the Δ^{12} -desaturase is a microsomal enzyme requiring either NADH or NADPH, with NADPH being the preferred electron donor. The addition of CoA stimulates the reaction, presumably by maintaining oleate in the CoA form. The optimal substrate concentration for desaturation is about 12 μ M. Radiolabeled linoleate is recovered primarily in the phospholipid fraction accounting for 9-11% of the labeled fatty acid. Lesser amounts of linoleate, 3-5%, are recovered from the triacylglycerol fraction and as the CoA derivative. Results from experiments designed to determine whether the substrate for the Δ^{12} -desaturase, oleate, is in the form of a CoA derivative or esterified in a complex lipid will be presented.

#131

HEMOCYTIC ENCAPSULATION IN *DERMACENTOR VARIABILIS* (SAY). Lisa R. Eggenberger*, William J. Lamoreaux, and Lewis B. Coons, Biology Department, Memphis State University, Memphis, TN, 38152 USA

Epon particles were implanted in *Dermacentor variabilis* through incisions in the cuticle. Tissues were sampled at 1, 3, 12, 24 and every 24 hours up to 140 hours. Encapsulation began with degranulation of granulocytes at 1 hour post-implantation. At 3 hours post-implantation, the degranulation and disintegration of granulocytes formed a connective matrix at the Epon surface. Aggregating plasmatocytes attached to this matrix. Plasmatocytes and granulocytes continued to respond to degranulation and formed multiple layering by interdigitizing around the Epon particle. The most common junctional complex observed were gap junctions. At 12 hours, the inner layer became increasingly electron dense and continued until encapsulation was completed. Completion of the capsule was also marked by decreasing degranulation and migration of hemocytes from the outermost layers of the capsule.

#132

PURIFICATION AND CHARACTERIZATION OF *MANDUCA SEXTA* GUT LIPASE. G.J.P. Fernando-Warnakulasuriya* and M.A. Wells, Department of Biochemistry, University of Arizona 85721.

A lipase has been purified from *Manduca sexta* fifth instar larval gut contents. The gut homogenate was centrifuged and the supernatant, which has most of the activity, was passed through a column of cholate agarose. Almost all of the activity was bound to the column. The column was washed with 1% sodium deoxycholate to remove contaminating proteins and the brown color, and the lipase activity was eluted with 3% sodium cholate. The lipase was further purified by a Sephadex G-75 gel filtration column. The final purification involves a HPLC DEAE-5PW column. When the purified protein was subjected to SDS polyacrylamide gel electrophoresis, a single protein band with a molecular weight of 27,000 was observed. When the protein acted on triolein it produced 1,2 and 2,3 diolein as well as monoolein. The enzyme also has phospholipase activity. The enzyme has been difficult to purify due to its amphipathic character and rapid inactivation at or below neutral pH. Supported by NSF grant DMB 8416620.

#133

THE EFFECT OF STRESS ON *MANDUCA SEXTA* EPIDERMAL PROTEINS. Catherine M. Fittinghoff and Lynn M. Riddiford, Dept. of Zoology, University of Washington, Seattle, WA. 98195

The insect integument provides the insect's first barrier to heat and dehydration. In response to high heat, the epidermis synthesizes an array of proteins similar in molecular weight to the heat shock proteins identified in *Drosophila*. The heat shock proteins of *Manduca sexta*, however, are synthesized at much higher temperatures than those of *Drosophila*. In addition, *Manduca*, in contrast to *Drosophila*, maintains synthesis of normal proteins during heat shock. Furthermore, synthesis of certain cuticular proteins is apparently increased during high temperature.

Supported by NRSA ST32 GM 07270.

#134

DOUBLE-STRANDED RIBONUCLEASE IN THE GUT JUICE AND THE MIDGUTS OF SILKWORM, *BOMBYX MORI*.

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Double-stranded RNA (dsRNA) of cytoplasmic polyhedrosis virus (CPV) is highly resistant to degradation by pancreatic RNase in a high salt concentration. However, the degradation of CPV dsRNA was observed as a smear band on polyacrylamide gel electrophoresis when they were incubated with the gut juice or the midgut homogenate of *B. mori*. The reaction required divalent cations (Mg^{++} and Mn^{++}), and monovalent cations (NH_4^+ , K^+ and Na^+). The optimal pH range for the reaction was pH 7 - 10. The properties of the reaction was similar to that of RNase III.

#135

MOTION DETECTION IN MEDULLARY NEURONS OF THE FLESHFLY.
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Indiana University, Bloomington, Indiana, 47405, USA

We present the first data on the identity of motion sensitive cells in a fly's medulla. Lucifer-filled electrodes were used to record intracellularly from immobilized *Sarcophaga bullata*. Stimuli were rear projected square-wave gratings and spots under computer control.

We have recorded several types of response to motion. Although we have occasionally recorded from directionally selective cells, none have been stained. The simplest type of response was transient periodic depolarization at the contrast frequency of the moving grating. Such responses were recorded from the terminals of laminar monopolar cells (LMC) and higher order columnar transmedullary (Tm) cells. A second type of response was a sustained depolarization. Periodic ripple at the fundamental or second harmonic of the contrast frequency was sometimes recorded on top of the depolarization, but such phasic information was atypical. Both types of response were recorded from amacrine (Am) and columnar cells. A third type of response in Am cells was sustained hyperpolarization without ripple.

We frequently saw dye-coupling among medullary columnar homologues and also among dissimilar cells in networks extending through all three optic ganglia, e.g., an LMC, a medullary Am cell, and a Tm cell projecting to the lobula. Supported by NIH grants EY05903 and EY5163.

#136

TWO GENES UNDER THE CONTROL OF 20-HYDROXYECDYSONE IN THE MOSQUITO *Aedes Aegypti*. M.T. Hamblin, M.F. Wolfner and H.H. Hagedorn*, Departments of Entomology and Genetics and Development, Cornell University, Ithaca, NY USA 14853.

A gene, cloned from a genomic library of *Aedes aegypti*, has been found to be expressed in the follicle cells of the ovary after a blood meal by *in situ* hybridization to tissue sections. 20-hydroxyecdysone was shown to stimulate the expression of this gene by injection of hormone into females that had been blood fed and decapitated. The vitellogenin gene, which is also under the control of 20-hydroxyecdysone, is also expressed after a blood meal, but only in the fat body. We therefore have two genes that are under the control of the same hormone, but are expressed in different tissues. We are currently investigating the regulatory regions of these genes, looking for sequences that might be involved in tissue and hormonal control.

#137

MORPHOGENETIC EFFECT OF JUVENILE HORMONE ANALOG S-71639 ON THE COMMON CUTWORM, *SPODOPTERA LITURA* (LEPIDOPTERA: NOCTUIDAE). M. Hatakoshi* and M. Hirano, Takarazuka Research Center, Sumitomo Chemical Co., Takarazuka, Hyogo 665, Japan.

The application of juvenile hormone analog, S-71639 {2-[1-methyl-2-(4-phenoxyphenoxy)ethoxy]pyridine}, to day 0 last instar larvae of *S. litura* delayed the timing of pupal and larval-pupal intermediate molts in a dose-dependent manner. At higher doses supernumerary larval molt was induced on day 4. The main ecdysteroid peak (100ng/ml) in the larvae destined for supernumerary larval molt occurred one day earlier than that (300ng/ml) in the untreated. Neck-ligatured experiments suggested that the activity of the prothoracic glands (PG) was inhibited, but that the prothoracicotropic hormone release was accelerated by the application of S-71639. The activating effect of S-71639 on the brain was superior to the inhibitory effect on the PG. The induction of the 5th instar larval and supernumerary larval molts were compared by correlating to the changes of S-71639 concentration in the hemolymph in each case.

#138

ASPECTS OF THE MECHANISM THAT CONTROLS THE SEX RATIO AND THE BODY SIZE OF THE COCKROACH HUNTING WASP *AMPULEX COMPRESSA* (FABR.) (HYMENOPTERA: SPHECIDAE: AMPULICINAE). Wijnand R.B. Heitmans, Laboratory of Experimental Entomology, University of Amsterdam, Kruislaan 302, 1098 SM Amsterdam, The Netherlands.

Variable sex ratios in *A. compressa* occur as a maternal response to a yet unknown prey factor which is concerned with the size, the stage and the quality of the cockroach. Male wasps (haploid) emerge on all prey types within the range of prey acceptance. The production of the females (diploid) seems to be restricted to a critical amount of food in the prey, so that female size (= weight in mg.) never drops below a certain threshold. The causal mechanism underlying this phenomenon is badly understood.

No shift in sex ratio was observed in pilot experiments in which wasp-prey contacts were partially or completely prevented. However, prey condition (e.g. hunger vs. well fed) does affect to some extent. The performed experiments also give some information concerning the nature of the prey factor that must be detected by the female wasp to fertilize the egg.

#139

LEPIDOPTERAN LARVAL PROTEASES DIFFER FROM VERTEBRATE ENZYMES - IMPLICATIONS FOR PLANT PROTEASE INHIBITORS AS A DEFENSE AGAINST INSECTS. Jon G. Houseman, Department of Biology, University of Ottawa, Ottawa, Ont. Canada K1N 6N5

Alkaline proteases in the gut of the European cornborer were identified using synthetic substrates and nonspecific substrate azocasein and identification was confirmed with potential protease activators and inhibitors. Azocasein proteolysis continued to increase as pH of the reaction mixture increased and this was similar to the high alkaline protease which had maximal activity against BAPNA at a pH value greater than 10. A low alkaline trypsin hydrolyzed BAEE maximally at pH 9.0 and chymotryptic activity, measured with BTEE, was maximal at pH 7.5-8.0. The high alkaline trypsin appears to be the principle digestive enzyme since its pH optimum resembles total proteolysis and is consistent with high digestive pH values found in Lepidoptera. Soybean, ovomucoid and corn inhibitor were included in either cornborer or vertebrate trypsin and chymotrypsin assays. Ovomucoid and corn inhibitor were not effective at inhibiting cornborer protease, which for corn inhibitor is contrary to the hypothesis that plant proteinase inhibitors disrupt insect digestive events.

#140

UNUSUAL ASPECTS OF VITELLOGENIN PRODUCTION AND VITELLOGENESIS IN THE STABLE FLY, *STOMOXYS CALCITRANS*, AND THE FACE FLY, *MUSCA AUTUMNALIS*. (DIPTERA: MUSCIDAE). Jon G. Houseman*¹ and P.E. Morrison². Biology Departments 1) University of Ottawa, Ottawa, Ont. Canada K1N 6N5. 2) University of Waterloo, Waterloo, Ont. Canada N2L 3G1.

Changes during the reproductive cycle, in fat body hemolymph and ovarian proteins in the stable fly and face fly were characterized quantitatively and qualitatively using SDS-polyacrylamide gel electrophoresis. In the stable fly SDS-PAGE failed to identify egg proteins in both female fat body and hemolymph samples and comparisons between male and female stable fly hemolymph and fat body failed to detect a female specific protein. SDS-PAGE and immunoelectrophoresis were used to quantify changes in face fly proteins. Egg protein was detected in the haemolymph, approximately 30% of total protein, but was not detected immunologically in the fat body. SDS-PAGE of hemolymph samples showed female specific proteins which accumulated during the reproductive cycles but they did not correspond to a major protein in the fat body and no single major protein differed between male and female fat body proteins in the face fly.

#141

COCKROACHES (BLATTARIA) AS MODEL SYSTEMS FOR NEUROBIOLOGY: APPLICATIONS IN BIOMEDICINE. Ivan Huber, Dept. of Biology, Fairleigh Dickinson Univ., Madison, New Jersey, USA, 07940.

The usual aim of neuroendocrine research in cockroaches is pest control, but since there are many functional analogies between the human and cockroach systems, many findings in the insect are also applicable to biomedicine. The following are some examples. Cockroach preparations of axons and cell bodies resemble those of vertebrates and are easy to handle and study. Large individual neurons are easily accessible and identifiable for anatomical, biochemical and physiological research, while synaptic preparations are suitable for studies of transmitter molecules. The brain-corpora cardiaca-corpora allata and hypothalamic pituitary systems have useful analogies. Control of hormone biosynthesis is similar in cockroaches and vertebrates. Neuroendocrine regulation of fat body metabolism is of interest since the insect fat body and the vertebrate liver are functionally comparable. The use of cockroaches in other neurobiological studies (e. g., aging, regeneration, learning, olfaction and mechanoreception) and the many advantages of cockroaches as subjects for such studies are discussed and examined in further detail.

#142

STRUCTURE AND EXPRESSION OF GENE CODING FOR STORAGE PROTEIN 1 IN BOMBYX MORI (LEPIDOPTERA: BOMBYCIDAE). S. Izumi*, H. Sakurai, T. Fujii and S. Tomino, Department of Biology, Tokyo Metropolitan University, Tokyo, Japan.

Storage protein 1 (SP 1) is a major plasma protein of *B. mori* and its biosynthesis in the fat body is regulated in a stage- and sex-specific fashion. To investigate the regulatory mechanisms of SP 1 biosynthesis, gene sequence for SP 1 was cloned and its structure as well as expression was studied.

The SP 1 genomic DNA is about 4.7 kb in length and is composed of five exons. The deduced amino acid sequence indicated that SP 1 peptide is rich in methionine with signal sequence at the N-terminal region. The 5' flanking region of SP 1 gene includes TATA consensus sequence at 30 nucleotides upstream from the cap site. Nucleotide sequences homologous to those for transcription enhancement identified in other class II genes occur around the cap site of SP 1 gene. Northern blot hybridization of the fat body RNA demonstrated that the expression of SP 1 gene is regulated in a stage- and sex-specific fashion at the level of transcription. Cloned SP 1 gene was efficiently and faithfully transcribed from the cap site in a cell-free system derived from the cultured BmN cells.

#143

AGGREGATION PHEROMONES OF *DROSOPHILA*: A PHYLOGENETIC LOOK. L.L. Jackson*, R.J. Bartelt, A.M. Schaner, R.A. Moats and R.D. Leu, Department of Chemistry, Montana State University, Bozeman, Montana 59717.

Aggregation pheromones in concert with food odors regulate long-distance aggregation behavior in *Drosophila*. We have identified the aggregation pheromone components of a number of phylogenetic groups. Present evidence suggests that there is species specificity for production and for perception of these aggregation pheromones. Where phylogenies are well studied (e.g. the *virilis* group), we are making correlations with the evolutionary story and the species specific aggregation pheromone biology. Where evolutionary distances are less well studied, we are providing an assessment of evolutionary relationships between species in a totally new way.

#144

Electroantennogram Responses of the Mediterranean fruit fly, *Ceratitis capitata* (Wiedemann) to isolated and identified volatile constituents from males. E.B. Jang*, D.M. Light, R.A. Flath, J.T. Nagata and T.R. Mon, USDA-ARS, Tropical Fruit and Vegetable Research Laboratory, Hilo, Hawaii, 96720, and USDA-ARS, Western Regional Research Center, Albany, California, 94710.

Compounds from the odor of "calling", sexually mature, laboratory reared male Mediterranean fruit flies were isolated by headspace trapping on tenax columns and identified using gas chromatography/mass spectrometry techniques. Electroantennogram responses (EAGs) to 54 of the 69 identified compounds were tested on both males and females. Significant differences between the sexes in their responsiveness were found in 9 of the 54 compounds tested. There was no correlation between the amplitude of the EAG response and the relative amounts of compound identified. Behavioral bioassays on each of the 5 "major" identified compounds as well as various "blends" were tested. These results are discussed in relationship to the insect's antennal sensitivity to these putative "pheromone" components and other related pheromone studies.

#145

PARTIAL PURIFICATION OF A JUVENILE HORMONE III ALLATOTROPIC FACTOR FROM THE TOBACCO HORNWORM, *MANDUCA* *SEXTA*. W.P. Janzen* and N.A. Granger, Department of Cell Biology and Anatomy, University of North Carolina, Chapel Hill, NC 27514 USA.

An allatotrophic neuropeptide (JH III ATF) which stimulates the synthesis of JH III/JH III acid by the corpora allata has been partially purified from day 0 pupal brains of *Manduca sexta*. ATF activity was followed with a paired gland *in vitro* CA assay in which JH III/JH III acid synthesis was measured by a radioimmunoassay specific for the homolog and its acid. Pupal brains were first homogenized in 0.1M NaPO₄ and then centrifuged (8,000 xg, 10 min; 150,000 x g, 1h). The purification protocol thus far includes three procedures: ammonium sulfate precipitation (75% saturated) and two HPLC steps, hydrophobic interaction chromatography (HIC) and gel filtration (GF). HPLC-HIC was carried out on a TSK Phenyl-5PW column (Beckman) in 0.1 M NaPO₄ containing 20% ethylene glycol (EG) and 1 mM dithiothreitol (DTT). Elution was achieved with a decreasing gradient of ammonium sulfate (0.5 M to 0 M), with ATF activity eluting at 0.18 M. Active fractions were pooled and applied to a Bio-sil TSK-250 GF column (Bio Rad) in the NaPO₄-EG-DTT buffer. Silver staining of SDS-polyacrylamide gels of the pooled active fractions from HPLC-GF revealed three bands. Overall recovery of activity was 60% with a 1250-fold purification.

#146

YOLK UTILIZATION IN THE DEVELOPING EGGS OF *LACCO* *TREPHE* *GRISEUS* *GUERIN* (HEMIPTERA : NEPIDAE). E. Jayakumar and S. Mathavan*, School of Biological Sciences, Madurai Kamaraj University, Madurai 625 021 India.

During the course of its embryonic development the water scorpion, *Laccotrephes griseus* exhibited steady increase in the water content (50.6 to 84.2%), ash (3.4 to 10.7%) and protein (42.2 to 61.2%) and showed a steady decrease in fat (48.3 to 24.7%), carbohydrate (6.1 to 3.4%) and energy content (26.7 to 20.1 kJ/g dry wt). Of the total energy spent on embryonic metabolism in *L.griseus*, 11.5% was derived from the oxidation of protein, 3.9% from carbohydrate and 84.6% from fat. Thus fat is the main energy source for embryonic development. The dry weight of the egg is positively and significantly correlated to fat content/egg as well as fat utilized/egg during development. Similarly a positive significant correlation between fat content of egg and fat utilized/egg was obtained.

#147

STUDY OF RELATIONSHIP BETWEEN RELEASE AND PERCEPTION OF PHEROMONE. S. Kanauija*, K. E. Kaissling
Department of Chemistry, G.B. Pant University of Agriculture & Technology, Pantnagar, 263 145, India; Max-Planck-Institut für Verhaltensphysiologie Seewiesen, West Germany.

In electrophysiological and behavioural experiments, stimulant is impregnated either on a piece of filter paper or on cotton which after evaporation of solvent is placed in a glass tube (cartridge). The results are generally interpreted according to the amount applied on the filter paper or cotton. But it depends on the amount released during stimulation and more correctly on the amount perceived by the sensory organs. These studies are, therefore, an attempt to relate the amount of chemical stimulant applied on the source to the amount released and perceived under different conditions using radiolabelled pheromone of female moth Antheraea polyphemus and freshly isolated antennae of the male moth.

#150

BILIVERDINE BINDING PROTEIN AND ITS ROLE IN LIGHT-INDUCED GREEN PIGMENTATION OF THE BUTTERFLY GRAPHIUM SARPEDON.

Y. Kato*, Department of Biology, International Christian University, Tokyo 181, Japan, and H. Yamada, Yakult Institute, Tokyo 186, Japan.

Green coloration in insects has a cryptic function, and is due to the mixture of blue component and yellow one. The integument of G. sarpedon larvae normally shows green color, which depends on the presence of blue protein, i. e., biliverdine binding protein (BP). But when the larvae are kept in a darkness from hatching, larval color remains yellow, and BP is absent in the epidermis. Light irradiation to a yellow larva increases the amount of BP in the epidermis and leads to the green pigmentation without intervening a molt. This light effect is seen not only at larval stage but also at pupal and adult stages. Presumably, light will stimulate the accumulation (synthesis or uptake from haemolymph) of BP in the epidermis via unknown process. We describe here the property of BP, which seems to be unlike that of Manduca or Locusta, and effect of light irradiation in this butterfly.

#148

STRUCTURE OF APOLIPOPHORIN-III FROM LOCUSTA MIGRATORIA.

M.R. Kanost*, H.M. Holden, I. Rayment, and M.A. Wells,
Department of Biochemistry, University of Arizona, Tucson, Arizona 85721.

Apolipophorin-III (apoLp-III) is a low molecular weight hemolymph protein which becomes associated with the low density lipophorin found during flight of insects which use lipids as the major fuel for flight. The role of apoLp-III in lipid transport appears to be to increase the lipid carrying capacity of lipophorin by covering the expanding hydrophobic surface resulting from diacylglycerol uptake. To determine what structural features might account for the lipid binding function of apoLp-III, we have isolated and determined the sequence of a cDNA clone of apoLp-III from Locusta migratoria. The deduced sequence of the mature protein is a 161 residue polypeptide with a molecular weight of 17,229. The sequence contains two putative N-linked glycosylation sites. Computer-assisted sequence analysis revealed that the protein has a potential for forming amphipathic helices, which may be important in its function as a lipid binding protein. The protein has been crystallized, heavy metal derivatives have been prepared, and x-ray diffraction studies are in progress to determine its three dimensional structure. Supported by NIH grant HL39116.

#149

EVOLUTION OF THE VITELLOGENIC PROTEINS DURING THE BIOLOGICAL CYCLE OF SARCOPHAGA ARGYROSTOMA (DIPTERA):

ULTRASTRUCTURAL AND ELECTROPHORETICAL STUDIES. A. Karlinsky, H. Mendes*, J. Schoeller-Raccaud and S. Vengadabady, Laboratoire de Physiologie des Insectes, Université P. et M. Curie, 7 Quai St Bernard, 75005, Paris, France.

The presence of vitellins in the hemolymph and ovaries of vitellogenic females can be detected by different electrophoretic methods.

We have observed by SDS PAGE that the accumulation and degradation of the vitellin subunits does not occur synchronously during the development of the insect.

One of the vitellin subunits, V₃, is already present in both the ovaries and hemolymph of the freshly emerged adults. On the other hand, the same subunit V₃ seems to persist in all stages of development, which poses the problem of its identity.

Hence we have undertaken two types of studies:

firstly, ultrastructural studies to trace the uptake of material by the ovaries; secondly, two-dimensional electrophoretic studies with the protein samples of the embryos, larvae as well as hemolymph and ovaries of the previtellogenic and vitellogenic females, for better understanding of the evolution and identity of each subunit.

#111

SPERMATOPHORE FORMATION IN THE GYPSY MOTH (*LYMANTRIA DISPAR* LEPIDOPTERA: LYMANTRIDAE). M. Kiuchi* and G. M. Happ, Department of Zoology, University of Vermont, Burlington, Vermont 05405, USA.

The elaborate spermatophore of the gypsy moth is deposited within the bursa of the female within 30 minutes after the start of copulation. This spermatophore is a product of the male accessory glands, the vasa deferentia, seminal vesicles, and ejaculatory duct. The major proteins characteristic of each of these male organs and the spermatophore have been compared by polyacrylamide gel electrophoresis. During the formation of the spermatophore, some of the secretory bands of the organs appear to be transformed into others of differing electrophoretic mobility. The relationship between the bands of the organs and those of the spermatophore will be examined. In addition, polymorphism within and among populations of gypsy moths will be explored. (Supported in part by USDA Competitive Grant No. 87-CRCR-1-2488).

#112

CHARACTERIZATION OF TRANSPORT SYSTEMS FOR CHOLINE AND ACETYLCHOLINE IN INSECT SYNAPTOSOMES.

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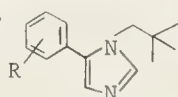
Acetylcholine is supposed to be a major neurotransmitter in the central nervous system of insects. Therefore neurochemical aspects of cholinergic synapses are of particular interest for insect neuropharmacology. We know from preceding studies that synaptosomal fractions isolated from ganglia of locust are highly enriched in cholinergic nerve terminals which contain a high-affinity transport system for choline, as uptake system which appears to be unique for cholinergic nerve endings and regulates the rate of synthesis for acetylcholine. Aspects of energetics and regulation of the specific choline carriers have been studied using locust synaptosomes as well as synaptosomal membrane vesicles indicating that the symmetric carrier-system is energized by ion gradients and can be regulated via presynaptically located receptors.

Towards a molecular identification of the specific transport system tritiated hemicholinium-3 has been employed in binding studies and attempts have been made to raise monoclonal antibodies specific for the carrier protein. The release of acetylcholine has been studied using a microperfusion technique; it was found that the evoked release of ACh can be regulated via presynaptic auto- and heteroreceptors. The autoreceptors for ACh appear to be muscarinic mainly of the M_2 -subtype which modulate the release rate by effecting the level of cAMP in the nerve terminal.

#113

INDUCTION OF PRECOCIOUS METAMORPHOSIS BY 1,5-DI-SUBSTITUTED IMIDAZOLES WITH A NON-TERPENE CHAIN. E. Kuwano*, M. Kikuchi and M. Eto, Department of Agricultural Chemistry, Kyushu University, Fukuoka 812, Japan.

A new series of 1,5-disubstituted imidazoles with a non-terpene chain has been synthesized and tested for their effects in inducing precocious metamorphosis when topically applied to the silkworm, *Bombyx mori*. In the 1-substituted-5-phenylimidazole series, the 1-neopentyl analog showed activity comparable with that of KK-22 (1-citronellyl analog). From a preliminary study of the structure-activity relationship, two representative compounds, 1-neopentyl-5-(2-ethoxyphenyl)imidazole (KK-110) and 1-neopentyl-5-(4-chlorophenyl)imidazole (KK-135) have been found to show high orders of activity. The ED_{50} values of KK-110 and KK-135 for 4th instar larvae were 1.6 and 1.8 $\mu\text{g/larva}$, respectively.



KK-110 : R=2-OC₂H₅

KK-135 : R=4-Cl

#114

DISTRIBUTION OF PROCTOLIN IN RHODNIUS PROLIXUS STAL.

A.B. Lange, I. Orchard and F.M. Barrett, Department of Zoology, University of Toronto, Toronto, Canada M5S 1A1.

Reversed-phase, high performance liquid chromatography (RP-HPLC) coupled to a sensitive bioassay has been used to determine the amount and distribution of proctolin in the CNS and viscera of adult, female *Rhodnius prolixus*. In addition, an anti-proctolin antiserum was used for immunohistochemical identification of proctolin-containing somata and terminals.

The mesothoracic ganglionic mass contained most, and the brain least, of the 378 fmol proctolin present in the CNS. Proctolin was also found in the reproductive and digestive systems with large amounts in the oviducts and high concentrations per mg tissue protein in the oviducts, ovary and hindgut.

The size and number of proctolin-immunoreactive neurons in each ganglion was consistent with the quantitative measures of proctolin content obtained with RP-HPLC. Over 200 such neurons were localized on both dorsal and ventral aspects of the ganglion. Terminals showing immunoreactivity with anti-proctolin antiserum were also observed on the hindgut and oviducts.

The identification of a population of proctolinergic neurons in *Rhodnius* provides a basis for future research into their physiological actions and behavioural significance.

#115

EFFECT OF INGESTED SOYBEAN PROTEASE INHIBITOR ON GROWTH AND DIGESTIVE PROCESSES IN EUROPEAN CORNBORER, *OSTRINIA NUBILALIS*, LARVAE (LEPIDOPTERA: PYRALIDAE). A.M. Larocque* and Jon G. Houseman, Department of Biology, University of Ottawa, Ottawa, Ontario, Canada K1N 6N5.

The proposed defensive role of plant protease inhibitors is being tested using the European cornborer and inhibitors chosen from plants that the insect severely attacks (corn), frequently attacks (tomato, potato) and from plants that are avoided (tobacco, soybean). We report here the results of our studies on effects of soybean trypsin inhibitor on growth and *in vivo* digestion which were monitored both in short term and extended studies. Protease assays were optimized for *O. nubilalis*, high alkaline trypsin, low alkaline trypsin, chymotrypsin, aminopeptidase and total proteolysis. Results indicated three trends which include a reduction in weight of treated animals compared to control, reduced proteolytic activity in treated animals and increased protein content in the gut of soybean fed animals. Ingested soybean trypsin inhibitor is detrimental to the larvae of *O. nubilalis* and currently the effects of ingested corn inhibitor are being examined.

#116

A CYTOMETRIC INVESTIGATION OF THE EFFECTS OF 20-HYDROXYECDYSONE ON CELL CYCLING IN PRIMARY CULTURES: ACCUMULATION IN G2 FOR EPITHELIAL AND MUSCULAR CELLS FROM THE MALE ACCESSORY GLAND OF *TENEbrio MOLITOR*. J.J. LENOIR-ROUSSEAU* and G.M. HAPP** *Lab. Biol., UFR Sciences, U. Paris XII, 94010 CRETEIL-FRANCE, **Zoology Dpt., U. of Vermont, 05405 BURLINGTON-USA.

The male accessory gland is composed of a muscular tunic which surrounds an epithelium that secretes precursors of the adult spermatophore. We explored the pupal stage, in which cell cycling arrests in G2 at the peak of ecdysteroid. Glands from newly-ecdysed pupae were dissociated with trypsin. In Landureau's S-20 medium with or without 10% heat-inactivated FCS, muscle cells form loose networks and epithelial cells form aggregates. Cells at densities of $5 \times 10^5/\text{ml}$ were incubated for 24 hr in basal medium at 25°C and then in medium with 20-hydroxyecdysone (10^{-8} to 10^{-4}M) for 24 hr. In the last 4 hr, cell cycling was blocked with colchicine. Mitotic activity increased logarithmically with hormone dose; the rate of increase with FCS ($y=4.99 \times 0.111$) was double that without FCS ($y=21.03 \times 0.163$).

After isolation of nuclei with NP40 and staining with propidium iodide and fluoresceine isothiocyanate, the accumulation of cells in G2 was estimated by the ratio $G2+M/G0+G1$ using an Ortho paradigm. The ratio increased with hormone dose (10^{-9} to 10^{-3}M). The response was flat between 10^{-5} and 10^{-4}M and declined at 10^{-3}M ecdysteroid. These results with primary cell cultures confirm those reported earlier with organ cultures (Yaginuma et al. Dev. Biol. 1988, 126: 173) and demonstrate unequivocally that the molting hormone acts in G1 as well as in G2.

#117

LE TEGUMENT DES CHENILLES, SITE DE BIOACCUMULATION PIGMENTAIRE, MINERALE ET PURIQUE. J. Lhonoré Labor. d'Histophysiologie Fondamentale et Appliquée. (URA 680, CNRS) 12 rue Cuvier 75005 - Paris - France.

L'application conjointe de la Microanalyse X a des coupes histologiques du tégument d'une trentaine d'espèces de Lépidoptères a permis d'établir une relation entre le type de livrée et les catégories d'inclusions épidermiques qui traduisent une bioaccumulation.

Les aires cuticulaires mélanisées sont toujours minéralisées. Les cellules épidermiques sous-jacentes sont chargées de nombreux grains d'omochrome (omochromosomes), siège d'une bioaccumulation de phosphate de calcium et de magnésium.

Les plages épidermiques blanches ou jaunâtres sont formées de cellules saturées en inclusions biréfringentes (microcristaux) qui correspondent à la bioaccumulation de composés puriques (urate de potassium prédominant).

En conclusion, outre sa fonction éthologique (livrée spécifique) et son rôle de filtre à radiations, le tégument constitue une réserve de composés minéraux et puriques réutilisables durant la nymphose.

#118

BIOACCUMULATION PIGMENTAIRE, MINERALE ET PURIQUE DANS LES YEUX DE *Pieris brassicae* L. (LEPIDOPTERA: PIERIDAE). J. Lhonoré, Labor. d'Histophysiologie Fondamentale et Appliquée. 12 rue Cuvier 75005 - Paris - France. (URA 680, CNRS).

La couleur des yeux d'insectes est déterminée par des pigments qui jouent le rôle d'écran aux radiations lumineuses: les omochromes et les ptérides. Le développement de techniques microanalytiques a permis de rapporter cet organe à un site de bioaccumulation.

Les cellules pigmentaires distales (CP1) sont le siège d'un dépôt purique dont l'urate de potassium est le constituant majeur. Les cellules pigmentaires proximales (CP2) et basales (CP3) montrent une bioaccumulation pigmentaire et minérale (phosphate de calcium et de magnésium).

En conclusion, les microcristaux des CP1 pourraient compléter le rôle du cristallin en focalisant les rayons lumineux ou en réalisant un "guide d'onde"; les cellules pigmentaires CP2 et CP3 participent à la bioaccumulation de sels minéraux et jouent simultanément le rôle d'écran en limitant la diffusion latérale de la lumière.

#119

OXIDATIVE METABOLISM OF CATECHOLAMINES BY TYROSINASES FROM THE INTEGUMENT OF PUPAL *MANDUCA SEXTA*. T.D. Morgan¹, M. Yonekura^{2,3}, K.J. Kramer^{2,3}, and T.L. Hopkins^{1,4}, Departments of Entomology¹ and Biochemistry², Kansas State University (66506) and U.S. Grain Marketing Research Laboratory ARS, U.S. Department of Agriculture³, Manhattan, KS, U.S.A. 66502.

Insect cuticle is sclerotized in part by highly reactive quinonoid metabolites crosslinking the protein and chitin polymers in the presumptive exocuticle. These sclerotizing agents are mainly the products of tyrosinase or phenoloxidase catalyzed oxidation of N-acetyldopamine and N-B-alanyldopamine. We have isolated and purified soluble forms of tyrosinases from the integument of pharate pupal *Manduca sexta* (L.). The sedimentation coefficients of the enzymes separated by sucrose density gradients ranged from 10S to 40S. A highly purified 14S enzyme was capable of hydroxylating tyrosine at a low rate and oxidizing diphenols to quinones at a much higher rate. The formation of o-benzoquinone was monitored by liquid chromatography with electrochemical detection (LCEC) using ascorbic acid as a reducing agent and benzenesulfonic acid as a nucleophilic quinone trap. The formation of N-acetylnorepinephrine or N-B-alanylnorepinephrine as determined by LCEC indicated tautomerization of o-quinones to p-quinone methides occurs followed by the addition of water to electrophilic sites. Chemical oxidation of the catecholamines with sodium periodate gave similar results suggesting that the enzyme had little influence on the extent of tautomerization. The data support formation in insect cuticle of o-benzoquinones and p-quinone methides as sclerotizing agents which then form covalent bonds via the ring or side-chain respectively with nucleophilic groups on cuticular biopolymers. (Supported in part by National Science Foundation Grant No. DCB-8609717.)

#120

GLYCOGEN PHOSPHORYLASE AND THE REGULATING ENZYMES IN THE SILKWORM, *BOMBYX MORI*. Isao Morishima, Department of Bioresource Science, Tottori Univ., Tottori, 680 JAPAN

Glycogen phosphorylase b was purified to homogeneity from pupal fat body of the silkworm, *Bombyx mori*. The molecular weight of the enzyme was estimated to be 92,000 - 95,000 by means of both SDS-PAGE and gel-filtration, showing the enzyme was a monomeric protein distinct from the vertebrate enzyme. Phosphorylase kinase purified from pupal fat body activated the phosphorylase b to generate phosphorylase a. Phosphorylase kinase from rabbit muscle similarly activated fat body phosphorylase b. The phosphorylase a thus generated was dephosphorylated by phosphorylase phosphatase purified from the same tissue. The fat body phosphatase existed as an inactive form in the homogenate. The enzyme was activated by the treatment such as repeated freezing-and-thawing or partial digestion by trypsin, which caused dissociation of catalytic subunit which had tightly bound to a regulatory component. Detailed properties of these enzymes will also be presented.

#121

PHARMACOLOGICAL EFFECTS ON HEAT INDUCED DEATH OF CULTURED CELLS OF THE MEDITERRANEAN FRUIT FLY (*CERATITIS CAPITATA*) (DIPTERA: TEPHRITIDAE). J.I. Moss* and B.B. Jang.

Investigations into the mechanisms of cell death at moderate temperatures were carried out. In many cases heat is the only available postharvest disinfection treatment for fruit flies in fruits and vegetables. Thermally induced cell death is also important to food processing and medical science.

Cell viability was measured by trypan blue exclusion and uridine uptake. Calcium channel blockers cobalt and lanthanum (millimolar) lowered the survival rate. Heating in low calcium saline reduced cell survival. Verapamil was ineffective. EDTA also reduced cell survival of heat treatments. Dinitrophenol also reduced cell survival in the presence of heat. It appears that calcium may protect these cells from heat induced death. This could be via entry into the cells or by external stabilization of the cytoplasmic membrane.

#122

BIOSYNTHESIS OF LIPIDS IN PUPAE OF THE TOBACCO HORNWORM, *MANDUCA SEXTA*. Dennis R. Nelson* and James S. Buckner, Metabolism and Radiation Research Laboratory, USDA-ARS, State University Station, Fargo, North Dakota, USA, 58105.

Long-chain methyl-branched alcohols of unknown function or metabolism have been found internally in tobacco hornworm pupae. The incorporation of radiolabeled acetate and propionate has been measured to determine the metabolism of the alcohols as compared to other internal lipids throughout the pupal stage. Triglyceride (TG) was the major lipid synthesized to day 4 and after day 16. Hydrocarbon synthesis was 10-20% of TG and tended to parallel that of the TG. Free fatty acids were formed until day 4. Between days 6 and 14 alcohols and wax esters were the major lipids synthesized, had reached maximum rates of synthesis by day 10 and negligible rates of synthesis by day 14.

#123

OVIPOSITION STIMULANTS OF SWALLOWTAIL BUTTERFLIES

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Oviposition stimulants of two oligophagous swallowtail butterfly species (Papilionidae) were isolated from their host plants. Gravid females of these butterflies responded selectively to methanolic extracts from their own host plants and laid eggs when the extracts were dispensed to filter paper and brought in contact to the females' fore-legs. Using this bioassay method, oviposition stimulants of a Rutaceae-feeding swallowtail, *Papilio xuthus*, were isolated from leaves of *Citrus unshiu*, and characterized as a mixture of vicenin-2, narirutin, rutin, adenosine, 5-hydroxy-*N*-methyltryptamine, bufotenine, (-)-synephrine, stachydrine and D-(+)-*chiro*-inositol. An artificial blend of these ten components elicited significant oviposition response apparently identical to that induced by contact with intact citrus leaves. Oviposition stimulants of an Aristolochiaceae-feeding swallowtail, *Atrophaneura alcinous*, were extracted from leaves of *Aristolochia debilis*, and characterized as a mixture of aristolochic acid I and B, sequoyitol, and 3-hydroxy-4-methoxycinnamoylmalic acid. Host recognition at the contact phase in their oviposition sequences seemed to be determined by the multi-component system of the host plant chemicals.

#124

PRIMARY SEQUENCE OF A SERINE PROTEASE INHIBITOR FROM HEMOLYMPH OF *MANDUCA SEXTA*. S.V. Prasad*, M.R. Kanost, and M.A. Wells, Department of Biochemistry, University of Arizona, Tucson, Arizona 85721.

A cDNA clone isolated from a *Manduca sexta* fat body cDNA library has been sequenced and shown to code for a 42,000 dalton protein homologous to the serpin family of serine protease inhibitors. The amino acid sequence of the *Manduca* protein is approximately 30% identical to human alpha-1 protease inhibitor, alpha-1 antichymotrypsin, antithrombin-III, and chicken ovalbumin, all members of the serpin superfamily. The protein sequence contains a putative N-linked glycosylation site. A protein of $M_r = 48,000$ isolated from hemolymph of *Manduca* larvae has an N terminal sequence identical to that deduced from the cDNA clone and inhibits bovine trypsin and trypsin purified from *Manduca* midgut. The mRNA for the *Manduca* serpin is present in fat body during the feeding stages of larval stadia, disappears during the pupal stage, and is again present in the adult. The role of serpins in insect physiology is not yet known. Supported by NIH grant HL39116

#125

GREENBUG TOXINS INJECTED INTO SORGHUM PLANTS. J.C. Reese*, R. Ma, and D.J. Schmidt, Department of Entomology, Kansas State University, Manhattan, KS 66506 and Paula Bramel-Cox, Department of Agronomy, Kansas State University, Manhattan, KS 66506.

Evidence has been obtained, separate and apart from the feeding insect, for a greenbug-produced toxin injected into sorghum. Damage can be quantified with spectrophotometric methods. Damaged tissue induces more rapid greenbug growth. The nature of the toxin and its effect on feeding behavior will also be discussed.

#126

REGULATION OF JH BIOSYNTHESIS AND TITRES BY OVARIES, MATING AND EGG LAYING IN *ACHETA DOMESTICUS* (ORTHOPTERA) M. Renucci, R. Augier, P. Charpin, C. Strambi and A. Strambi.
C.N.R.S.- L.N.B. 5 ; BP 71 - 13402 Marseille cedex 09 - FRANCE.

In *A. domesticus*, mating-induced egg laying led to an increased JH titre and to the growth of penultimate and terminal oocytes. In females not allowed to lay eggs, mating did not act on ovarian development nor on JH titres.

Hemolymph JH levels, in mated ovariectomized females, were not different from virgin ovariectomized females.

JH biosynthesis did not differ between virgin and mated-egg laying females. However it was significantly lower in ovariectomized females.

The correlation between biosynthesis and hemolymph titres was positive in control females and negative in ovariectomized animals.

In *A. domesticus*, the increase of JH hemolymph titre observed in mated-egg laying females can clearly be correlate to the rapid ovarian growth following egg laying and not to mating.

#127

PURIFICATION AND CHARACTERIZATION OF VITELLIN FROM THE EGGS OF *DERMACENTOR VARIABILIS*. Rosemarie Rosell-Davis* and Lewis B. Coons, Department of Biology, Memphis State University, Memphis, TN, USA 38152

We purified vitellin from the eggs of the hard tick, *D. variabilis* using gel filtration and ion exchange chromatography. Two vitellin proteins were identified and were designated A and B. The molecular weights were determined to be 480 and 370 kD and the isoelectric points were at pH 6.1 and 6.25, respectively. The absorption maxima for both proteins were at 280 and 400 nm. The vitellins were hemoglycolipoproteins as detected by selective staining of polyacrylamide gels, carbohydrate analysis and lipid analysis. The proteins both reduced to six major polypeptides by SDS-PAGE. Polyclonal antibodies directed against the proteins were developed in rabbits. Antivitellin antibodies were used to identify the female midgut and fat body as the sites of synthesis of vitellogenin which is immunologically identical to vitellin. These findings support previous studies that the midgut is a second site of vitellogenin synthesis in the hard tick.

#128

IN VITRO ECLOSION HORMONE SYNTHESIS AND SECRETION IN THE SILKWORM, *BOMBYX MORI*. Mika Sakakibara* and Hajime Fugo, Department of Sericulture, Tokyo University of Agriculture and Technology, Fuchu, Tokyo 183, Japan.

Ten brain-corpora allata (Br-CA) complexes taken out from the pharate-pupae were incubated in 1 ml of the CSM-2F medium under 16L-8D photo-condition at 25°C. Eclosion hormone (EH) activity in brain, CA and medium was determined by Bombyx EH assay, respectively. EH titer in a brain just before incubation was 1-2 units, but the titer gradually increased with age and became 4-5 units on the 12th day. Although the EH titer in CA at the beginning was scarcely detected, its titer on the 12th day was 3-4 units/pair. The EH activity in the medium could not be detected up to the 12th day, but it was found on the 13th day and its titer was 50 units per ml. Molecular weight of the EH in brain, CA and medium was estimated to be 8,000 ± 2,000 daltons. It is suggested that the brains in the medium respond to the day-night cycles and the synthesized EH in the brains was secreted into the medium through the CA on the proper day.

#129

CONDITION IN DIAPAUSE INDUCTION AND PHYSIOLOGICAL CHANGES DURING DIAPAUSE OF THE LADYBIRD, *COCCINELLA SEPTEMPUNCTATA BRUCKII* (COLEOPTERA: COCCINELLIDAE). H. Sakurai* and S. Takeda, Laboratory of Entomology, Faculty of Agriculture, Gifu University, Gifu, Gifu Prefecture, Japan 501-11.

C. septempunctata bruckii found in Japan is basically bivoltine, in which the 1st-generation adults aestivate and the 2nd-generation hibernates. Ultrastructural study on the endocrine system showed a change signifying inhibition of corpus allatum during aestivation period. Ultrastructural changes were also found in the flight muscle and the mid gut related to inhibition of the respiration and the digestion during aestivation period, respectively. Observation indicates that the aestivation is the true diapause controlled by corpus allatum, while the hibernation is not. Rearing experiment demonstrates that the summer condition (high temperature and long photoperiod) acts to induce the diapause, whereas the autumn condition (mild temperature and short photoperiod) does not inhibit metabolic activity of adults. It can be understood that the aestivation of *C. septempunctata* in Japan is the diapause type adapted to climate of temperate latitudes.

#130

REGULATION OF ECDYSTEROID TITER IN HEMOLYMPH: ROLES OF PROTHORACIC GLAND AND DEHYDROECDYSONE REDUCTASE. Sho Sakurai*, Dorothy B. Rountree, James T. Warren and Lawrence I. Gilbert, ¹Department of Biology, Kanazawa University, Kanazawa 920, Japan and Department of Biology, University of North Carolina, Chapel Hill, N.C. 27514, U.S.A.

Prothoracic gland of day 0 pupae of the tobacco hornworm, *Manduca sexta*, has been shown to produce a 2:1 mixture of 3-dehydro- and 2-dehydroecdysone (DE) in addition to ecdysone *in vitro*. Amount of DE was much larger than that of ecdysone. DE has been demonstrated to be almost inactive in an *in vitro* assay using the chromosome puffing of *Drosophila* salivary gland (Richards, 1978). Contrary, it is active in a bioassay using *Sarcophaga* mature larvae, suggesting that the activity of dehydroecdysone reductase in hemolymph may be important to regulate the concentration of biological active ecdysteroids in hemolymph. Thus, we determined the amount of DE and ecdysone produced by prothoracic gland every day in the 5th larval instar and early pupal stage. The reductase activity in hemolymph was also determined through the same period.

#131

ACTION SPECTRA AND BRAIN PHOTORECEPTION IN THE CALLING CLOCK OF THE CUCUMBER LOOPER MOTH (LEPIDOPTERA: NOCTUIDAE). M. Sasaki* and S. Yamazaki, Laboratory of Entomology, Faculty of Agriculture, Tamagawa University, Machida, Tokyo 194 Japan

Action spectra for driving and phase-shifting the calling clock in the cucumber looper moth, *Anadevidia peponis* were determined with the Okazaki large spectrograph, which created pure monochromatic lights (275–700nm, every 25nm and known energy level of 0.01–100 $\mu\text{W}\cdot\text{cm}^{-2}$). Action spectrum for driving clock was evaluated from the dose response of presence or absence of the onset of oscillation. Two hour-irradiation was applied onto the head of moths which had been kept in continuous darkness. On the other hand, the spectrum for delaying phase-shift was determined by measuring the energy level equivalent to 50% delay of the maximum caused by white, strong light.

There was a distinct peak in sensitivity at around 375 nm in both driving and phase-shifting effects. As to the wave length of 475nm, it was most effective in driving (energy for 50% response; 10 $\text{nW}\cdot\text{cm}^{-2}$), while least sensitive in phase-shifting (10 $\text{nW}\cdot\text{cm}^{-2}$). The similar responsibility of eyeless moths made by removing the eye disk at larval stage confirmed the extraretinal photoreception. The photoreceptor site was localized to be a limited area including MNSC by microirradiation of the brain surface.

#132

ACTIVATION OF TWO DIFFERENT PHENOLOXIDASES IN THE HEMOLYMPH OF *SARCOPHAGA BULLATA* LARVAE IN RESPONSE TO ZYMOSAN TREATMENT. S.J. Saul* and M. Sugumaran, Department of Biology, University of Massachusetts, Boston, Mass 02125.

In response to invading organisms, insects are known to encapsulate and melanize the foreign objects. Since phenoloxidase is responsible for melanin formation, it is usually assumed that the capsule is made up of melanin. Although sclerotin formation is also likely, this possibility has never been examined. In this paper, we present evidence for the activation of two different phenoloxidases – one responsible for the production of quinones and the other responsible for the production of quinone methides – in the hemolymph of *Sarcophaga bullata* larvae.

Sephacrose 6B column chromatography of the hemolymph activated with either zymosan or chymotrypsin, resulted in the separation of two different phenoloxidases. The higher M.wt form converted N-acetyldopamine to its quinone while the lower M.wt form did not produce the quinone. HPLC analysis of the reaction mixture in the latter case revealed the formation of N-acetylnorepinephrine consistent with the intermediate formation of quinone methide. Since quinone methide formation is associated with sclerotin, it is likely, that melanic capsule formed during immune response may contain sclerotin as well.

#133

REGULATION OF PHEROMONE SYNTHESIS IN THE GERMAN COCKROACH, *BLATTELLA GERMANICA* (L.) (DICTYOPTERA: BLATTELLIDAE). C. Schal, Department of Entomology, Rutgers University, Cook College, New Brunswick, New Jersey 08903, USA.

It is hypothesized that in cockroaches pheromone synthesis is under neuroendocrine regulation. In several species, juvenile hormone (JH) has been shown to induce pheromone production; allatectomies inhibit the synthesis and/or release of pheromones.

The adult female *B. germanica* produces three pheromone components as an epicuticular secretion. The titer of pheromone increases with age in virgin females. Mating accelerates the accumulation of cuticular pheromone, while gestation slows it considerably. *In vivo* incorporation of ¹⁴C-propionate into the pheromone follows a similar pattern, with low incorporation during previtellogenesis, high incorporation during vitellogenesis and following copulation, and again, low incorporation during gestation. This pattern reflects the pattern of JH synthesis by the corpora allata *in vitro*.

The effects on pheromone synthesis of allatectomies, anti-allatins, juvenile hormone analogs, and nutrition will be reported.

#134

AGGREGATION PHEROMONE IDENTIFICATION AND CHARACTERIZATION FOR THREE MEMBERS OF THE ANANASSAE SUBGROUP OF THE MELANOGASTER GROUP: *DROSOPHILA ANANASSAE*, *DROSOPHILA MALERKOTLIANA*, AND *DROSOPHILA BIPECTINATA*. A. M. Schaner*, K. J. Graham, L. L. Jackson, and R. D. Leu. Biochemistry Group, Chemistry Department, Montana State University, Bozeman, MT, USA, 59717.

(Z)-11-Octadecenyl acetate (Z11-18:Ac) and (Z)-11-eicosenyl acetate (Z11-20:Ac) were identified as the aggregation pheromone of *Drosophila ananassae*. Z11-20:Ac was identified as the aggregation pheromone of *Drosophila malerkotliana* and *Drosophila bipectinata*. The pheromones were isolated from the ejaculatory bulbs of mature males and transferred to the females during mating. Within hours after mating the females released the majority of the pheromone to the surrounding surfaces. Z11-18:Ac and Z11-20:Ac were not attractive alone, however, in combination with fermenting food or fermenting food odors, the acetates attracted flies of both sexes in a wind-tunnel olfactometer. Although *D. malerkotliana* and *D. bipectinata* males had no Z11-18:Ac, flies were as attracted to Z11-18:Ac as to an equal quantity of Z11-20:Ac. *D. ananassae* were attracted to Z11-18:Ac but not to Z11-20:Ac. However, Z11-20:Ac in combination with Z11-18:Ac was significantly more attractive than Z11-18:Ac alone.

#135

ISOLATION OF A cDNA CLONE FOR SP23, A SPERMATOPHORIN PROTEIN FROM THE ACCESSORY GLANDS OF MALE TENEBRIO MOLITOR (COLEOPTERA: TENEBRIONIDAE). M. B. Schwartz*, M. Peferoen, and G. M. Happ, Department of Zoology, University of Vermont, Burlington, Vermont 05405, USA.

The spermatophore of mealworm beetles is assembled from the proteinaceous secretions of the male accessory glands. One product of the bean-shaped accessory glands is SP23, a spermatophorin with an apparent molecular weight of 23 kDa and one that is proline-rich and lacks methionine [Shinbo *et al.*, (1987), J. Biol. Chem. 262:4794-4799]. We have constructed a cDNA library in lambda gt11 from the mRNAs of mature BAGs. After screening the library with monoclonal and polyclonal antibodies to Sp23, we isolated 13 positive clones. The insert from one of these clones was transferred to M13 and sequenced. The predicted structure of the protein and its possible similarities with other structural proteins will be discussed. (Supported in part by grants from the National Institutes of Health (GM-26140) and the USDA (87-CRCR-1-2406).

#136

THE ROLE OF HEMOLYMPH PROTEINS IN ABSORPTION AND TRANSPORT OF XENOBIOTICS. J.P. Shapiro, USDA, ARS, 2120 Camden Road, Orlando, Florida 32803.

Recently, insect hemolymph proteins have been implicated in the absorption and transport of natural and synthetic xenobiotics. The specific roles of proteins in toxification or detoxification are unknown, however.

Lipophorin isolated from larval hemolymph of *Diaprepes abbreviatus* (Coleoptera: Curculionidae) binds small hydrophobic compounds, such as the coumarins, that are absorbed from the diet. However, most absorbed coumarin appears to be bound by another more abundant protein in the hemolymph. This protein appears to be a larval storage protein, judging by the molecular weight of its subunit and its concentration in hemolymph.

Interactions of fluorescent compounds, such as the coumarins, with hemolymph proteins are readily studied using spectrofluorometric methods. Fluorescent energy transfer from hydrophobic amino acid residues of lipophorin to coumarins demonstrated association of xenobiotics with those residues, while fluorescence quenching experiments indicated permeation of lipophorin by the amphiphile acrylamide, but not by iodide ion.

#137

TRANSPLANTATION OF SILKWORM GONADS PRESERVED IN LIQUID NITROGEN. H. Shinbo, The Sericultural Experiment Station, Tsukuba, Ibaraki 305, Japan.

Ovaries and testes prepared from larvae of the silkworm, *Bombyx mori*, were cooled to -7°C at $1^{\circ}\text{C}/\text{min}$ using a programmable freezing machine, and held at -7°C for 10 min; they were then cooled again to -35°C at $0.3^{\circ}\text{C}/\text{min}$ and plunged into liquid nitrogen. After thawing, the frozen-thawed ovaries and testes were transplanted into the female and male larvae of the same stages, respectively, gonads of which had just been extirpated. When emerging as adult, the male and female adults were mated with non-treated female and male adults, respectively, and the mated females were allowed to oviposit. A few percent of the frozen-thawed ovary-transplanted female adults, which had mated with normal males, laid fertilized eggs. In addition, 1 of 109 normal female adults mated with the frozen-thawed testis-transplanted males laid fertilized eggs. The larvae hatched from the fertilized eggs possessed genetical marker of the donors and completed post-embryonic development. The results indicate that the silkworm ovaries and testes can retain their capacities for oogenesis and spermatogenesis, and the bands (ducts), which connected with the transplanted ovaries and testes, can connect with those of hosts after super-low temperature exposure.

#138

ELECTROPHYSIOLOGICAL PROPERTIES OF DEGENERATING NEUROMUSCULAR JUNCTIONS IN *MANDUCA SEXTA*. I. Sonea*, M. B. Rheuben, and C. Young, Department of Anatomy, Michigan State University, East Lansing, Michigan 48824, U.S.A.

During early pupation, the larval mesothoracic AB and C muscles (nomenclature from Lyonet, 1762) degenerate, permitting the comparison of normal and degenerating larval neuromuscular junctions (NMJs). Excitatory junction potentials (EJPs) were recorded intracellularly from these muscles in low calcium saline. The amplitudes and time courses of subthreshold EJPs recorded from larval C fibers were consistently greater than those recorded simultaneously from AB fibers. These characteristic differences persisted during degeneration, but the times-to-peak and to half-fall were often lengthened dramatically. When amplitudes of the 1st and 2nd of a train of EJPs were compared after 5 min. rest, facilitation generally occurred in larval AB but not C fibers at 6/sec and 20/sec. Pupal NMJs were very much more variable in response to trains, although AB fibers tended to facilitate more often than C fibers. There was a weak correlation between the tendency to facilitate and a smaller EJP amplitude.

#139

MORPHODYNAMIC PROPERTIES OF ENDOCRINE ACTIVITY OF MEDIAL CELLS IN BRAIN OF *SESAMIA CRAETICA*. D.L. Stevanović*, J. Milin and G. Grubić-Lajšić, Institute of Biology, Faculty of Natural Sciences and Mathematics, Novi Sad, Yugoslavia

The caterpillar *Sesamia craetica* in advanced diapause living under natural conditions was studied. Electron microscopy showed two pathways of the neurosecretion synthesis. The first one is granulated endoplasmic reticulum (GER) - giant prosecretory granules. It is recognized by fasciculated GER tubules, their subsequent dilatation into electron-lucent cysts deprived of ribosomes, and by final formation of large highly electron-dense prosecretory granules. The last mentioned ones were found in the very moment of extrusion too. The second pathway consists of the agranulated reticulum - small prosecretory granules. It is marked by polymorphous membrane profiles with focal condensation of the content, which later yields small highly electron-dense prosecretory granules. They are thickly distributed between the cystically enwidened GER tubules. The accumulation of the granules shows that these cells are in the phase of intensive synthesis and amassment of neurosecretion. The existence of the two-pathway neurosecretion synthesis indicates that at least two kinds of polypeptides are synthesized, which exert a synchronized activity in the further development.

#140

DIFFERENTIAL MECHANISM OF OXIDATION OF N-ACETYLDOPAMINE AND N-ACETYLNOREPINEPHRINE BY CUTICULAR PHENOLOXIDASE FROM *SARCOPHAGA BULLATA*. M. Sugumaran*, B. Hennigan, V. Semensi and W. Mitchell, Department of Biology, University of Massachusetts, Boston, Mass 02125.

The mechanism of oxidation of two related catecholamine derivatives viz., N-acetyldopamine (NADA) and N-acetylnorepinephrine (NANE) by cuticular phenoloxidase was studied. Enzymatic oxidation of NADA resulted in the formation of NANE as a soluble product in the reaction mixture, while bulk of the NADA got bound to the cuticle with the retention of catecholic function. Quinone formation could not be witnessed in the reaction. However, NANE oxidation by the cuticular enzyme resulted in the accumulation of its quinone in the reaction mixture. Covalent binding of this compound to cuticle could not be observed. NADA treated cuticle, but not NANE treated cuticle, upon acid hydrolysis liberated arterenone and 2-hydroxy-3',4'-dihydroxyacetophenone. These results further confirm the unique conversion of NADA to its quinone methide and NANE to its quinone by the cuticular phenoloxidase. The significance of the observed mode of oxidation, for sclerotization sarcophagid cuticle will be presented.

(Supported in part by N.I.H. Grant AI-14753)

#141

CHARACTERIZATION OF QUINONE METHIDE GENERATING CUTICULAR PHENOLOXIDASE FROM *MANDUCA SEXTA* LARVAE. M. Sugumaran*, T. Rivera, V. Semensi and S.J. Saul, Department of Biology, University of Massachusetts, Boston, Mass 02125.

Chitin bound cuticular phenoloxidase from *Manduca sexta* larvae, isolated during larval-pupal transformation exhibited a wide substrate specificity. While conventional quinone formation could be witnessed with certain catechols, such a product formation was not observable with both N-acetyldopamine and 3,4-dihydroxyphenylacetic acid. Rather the side chain of these compounds were oxidized resulting in the formation of colorless catechol cuticle adducts and soluble side chain oxygenated compounds. Radioactive trapping experiments failed to support the formation of dehydro N-acetyldopamine derivative from N-acetyldopamine. These results are consistent with the generation and subsequent reactions of quinone methides in the reaction mixture and confirm our hypothesis that quinone methides are formed during sclerotization of certain cuticle.

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#142

LIGNAN AS PHYTOCHEMICAL DEFENSE AGAINST INSECT—SYNTHESIS AND ABSOLUTE CONFIGURATION OF HAEDOXANS, THE INSECTICIDAL LIGNANS OF *PHYRYMA LEPTOSTACHYA* L.—

Eiji Taniguchi* and Fumito Ishibashi, Department of Agricultural Chemistry, Faculty of Agriculture, Kyushu University, Hakozaki 6-10-1, Higashiku, Fukuoka, Japan 812.

To establish the unique structures, involving absolute configuration, of haedoxans (A, D, C-acetate, F-acetate) of *Phryma leptostachya* L., (+)- and (-)-haedoxan were unambiguously synthesized. The (+)-(1S, 2S, 5R, 6S, 2'R, 3'R)-1-hydroxy-2-(2-methoxy-4,5-methylenedioxy)phenoxy-6-[7'-methoxy-3'-methoxymethyl-2'-(3,4-methylenedioxy)phenyl-2', 3'-dihydro-1', 4'-benzodioxin-6'-yl]-3,7-dioxabicyclo[3.3.0]octane was highly insecticidal as the natural haedoxan D, causing flaccid paralysis (LD₅₀: 0.005 µg / *Musca domestica* coadministered with piperonyl butoxide), while the (-)-(1R, 2R, 5S, 6R, 2'S, 3'S)-isomer showed no activity even at 10 µg. Haedoxans were highly insecticidal, especially in oral intake, on lepidopterous insects (*Spodoptera litura*, *Cnaphalocrocis medinalis*, *Plutella xylostella*, and so on). These lignans were detected in the leaves and stems, although at much less levels than in the roots. Lignans, the widely distributed and typical phenylpropanoid of higher plants, may take an important role for plants in their defense mechanism against insect-attack, and then they might serve to develop new methods for plant protection.

#143

#144

CHARACTERIZATION OF THE LIPOPHORIN RECEPTOR IN LARVAL FAT BODY FROM *MANDUCA SEXTA*. K. Tsuchida* and M.A. Wells, Department of Biochemistry, University of Arizona, Tucson, Arizona 85721.

The lipophorin receptor has been solubilized from the plasma membrane of *Manduca sexta* larval fat body with Triton X-100. Binding of lipophorin to the receptor requires calcium ion and is abolished by pretreatment of the receptor preparation with pronase. The receptor binds lipophorin with high affinity, K_d = 9.0 x 10⁻⁸ M. When analyzed by SDS PAGE and ligand blotting, a single receptor species with Mr about 150 KDa was observed. In *in vitro* studies with isolated fat body it was shown that when >90% of the diacylglycerol present in lipophorin was delivered to the fat body, less than 5% of the lipophorin apolipoproteins entered the fat body. These data suggest that the lipophorin receptor is a non-internalizing receptor, which is consistent with the suggestion that lipophorin is a reutilizable shuttle for lipid transport in insects. Supported by a grant from NIH HL39116.

#145

CHEMORECEPTION OF PHENOLIC ACIDS AND FLAVONOIDS IN LARVAE OF TWO *PIERIS* SPECIES. J.J.A. van Loon, Foundation for Agricultural Plant Breeding, P.O. Box 117, 6700 AC Wageningen, The Netherlands.

Chemosensory responses in two maxillary sensilla styloconica to stimulation with phenolic acids and flavonoids were studied using electrophysiological methods in caterpillars of *Pieris brassicae* L. and *Pieris rapae* L. Stimulus compounds and the concentrations tested were selected on the basis of reported occurrence in a common host plant, *Brassica oleracea* L. Of the five phenolic acids tested, chlorogenic and protocatechuic acids were the most effective stimulants. Out of seven examined, catechin was the most effective flavonoid stimulant in the lateral sensillum styloconicum of both species, while three others were not evoking responses at any of the concentrations tested. Chemosensory responses were generally increasing with increasing stimulus concentrations in the range tested (0.2 – 5.0 mM). *P. rapae* generally was less sensitive as judged by higher thresholds.

Mixture experiments revealed that in the lateral sensillum one and in the medial sensillum two cells were especially sensitive. Cyanin caused inhibition of spiking activity in several other neurones. Chemosensory responsiveness was reflected in preference behaviour in dual choice situations.

#146

MONOCLONAL ANTIBODIES: A POTENTIAL TOOL TO CHARACTERIZE NEUROPEPTIDES IN *PERIPLANETA AMERICANA* L. P. Verhaert*^{o+}, H. Walgraeve^o, R. Downer^o and A. De Loof⁺; ^o: Department of Biology, Waterloo University, Waterloo, Ont, N2L 3G1, Canada; ⁺: Zoological Institute, Naamsestraat 59, B-3000 Leuven, Belgium.

In immunohistochemistry (IHC) several monoclonal antibodies (Mabs) raised against vertebrate (neuro)hormonal peptides detect distinct neurons of the cockroach brain and/or corpora cardiaca (CC). Intensive staining is obtained with a Mab against substance P, a human growth hormone (hGH) Mab, an insulin-like growth factor I Mab and 4 Mabs recognizing different epitopes on human luteinizing hormone (hLH). These results confirm our previous observations using polyclonal antibodies (Pabs) and support the hypothesis that compounds resembling these vertebrate hormones occur in insects. However, in contrast to previous Pab studies, IHC with a second Mab to hGH, a fifth Mab to hLH, a Mab to somatostatin, glucagon, glucagon-like peptide and an insulin (INS) Mab failed to detect any epitopes in the blattarian brain or CC. This suggests that some of the insect peptides are different from their vertebrate equivalents. The very weak stainings with high concentrations of 2 different Mabs to human glycoprotein hormone (TSH) alpha-subunit and 4 more INS Mabs (3 to bovine, one to human INS) may be interpreted similarly. Additionally, staining in the *Periplaneta* brain/cc was obtained with Mabs to a *Locusta* CC-factor, a *Manduca* brain factor and *Bombyx* 4K-PTTH, suggesting homologies among different insect orders.

Studies are currently in progress to further characterize some of these materials using Mabs in Western blot analyses. The use of Mabs, combined with HPLC separation procedures, offers a considerable potential for the purification and isolation of insect peptides.

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#147

STRUCTURE OF *MANDUCA SEXTA* FAT BODY DURING THE FINAL LARVAL STADIUM. E. Willott*, L.K. Bew, R.B. Nagle, M.A. Wells, Department of Biochemistry, University of Arizona, Department of Pathology, University Medical Center, University of Arizona, Tucson, Arizona 85721.

The structure of the fat body during the final larval stadium was studied with light and electron microscopy. Major structural changes in the fat body include: a) acquisition of golgi complex (GC) and rough endoplasmic reticulum (RER) early in the stadium; b) lipid and glycogen accumulation during the feeding period; c) loss of many cellular organelles (such as GC and RER) when the insect stops feeding; d) accumulation of protein and urate granules during the prepupal period; e) development (during the feeding period) and abrupt demise (at the onset of the prepupal period) of a plasma membrane reticular system; f) change in shape of nucleus from roughly spherical (during the feeding period) to ellipsoid (in the prepupal period). These changes correlate well with known biochemistry of *M. sexta* fat body. Supported by a grant from NIH HL39116.

#148

20-HYDROXYECDYSONE IS REQUIRED TO COMMIT ACCESSORY GLANDS TOWARD TREHALASE PRODUCTION IN MALE *TENEbrio MOLITOR*(L.) (COLEOPTERA:TENEBRIONIDAE). T. Yaginuma and G. M. Happ*, Department of Zoology, University of Vermont, Burlington, Vermont 05405, USA.

During post-ecdysial adult maturation, the bean-shaped accessory reproductive glands (BAGs) of adult male mealworm beetles produce increasing amounts of trehalase. To determine when the BAGs become competent to produce trehalase, we transplanted pupal BAGs into 0-day female adults. Trehalase activity increased in implants from mid-pupae but not in BAGs from young pupae. BAGs from 0- and 2-day pupae were exposed to 20-hydroxyecdysone *in vitro* before implantation. Increase in trehalase activity was dose dependent. Both dose (ED_{50} : 5×10^{-6} M) and exposure time (> 6 hr) of hormone required are greater for commitment than for acceleration of pupal cell cycling. (Supported in part by Grant GM-26140 from the National Institutes of Health).

#149

RACEMIC N-ACETYLARTERENOL: MAJOR OXIDATION PRODUCT OF ENZYMIC ACTION ON N-ACETYLDOPAMINE IN PRAYING MANTID. M. Yago*, H. Sato and H. Kawasaki, Department of Biochemistry, School of Dentistry, Iwate Medical University, Morioka, Japan 020.

Our previous work showed the presence of 3-O- β -glucosides, N-acetyldopamine (NADA), and N-malonyldopamine in the left colleteral gland and the presence of a β -glucosidase in the right gland of the praying mantid, *Tenodera aridifolia sienensis* Saussure. In addition to the two corresponding aglucones, some of their derivatives oxidized at the β -position were present in the sclerotized ootheca. Some researchers also found the β -oxidized derivatives of NADA in the hydrolyzates of sclerotized cuticles of other insect species and identified N-acetylarterenol (NANA) as one of the oxidation products when NADA was incubated with insect cuticle. In particular, M. G. Peter and W. Vaupel reported that in *Manduca sexta*, NANA, the product of incubation of NADA with pupal cuticle powder, was racemic. As we previously found that NADA was converted into NANA by enzyme(s) in the left colleteral gland of the praying mantid, in the present experiment we attempted to determine if the NANA produced was also racemic. The results indicated that there was no stereoselectivity in the praying mantid, *Tenodera aridifolia sienensis* Saussure.

#150

INITIATION AND PROMOTION OF VITELLOGENESIS IN *AEDES AEGYPTI* BY TRYPTIC DIGESTS OF ALBUMEN AND GLOBULIN. C.L. Judson* and M.A. Montague, Dept. of Entomology, University of California, Davis, CA, U.S.A., 95616.

Certain tryptic digest fragments of gamma-globulin will initiate and promote vitellogenesis in this mosquito in the presence of trypsin inhibitor. Fragments of albumen digests, in contrast, will not initiate or promote in the presence of inhibitor, but do in the absence of inhibitor.

EVOLUTION OF SPECIES - AS VIEWED FROM AN INSECT HYBRID ZONE. G.M. Hewitt, School of Biological Sciences, University of East Anglia, Norwich, NR4 7TJ., U.K.

Genetic differences evolve through time so that finally no gene flow is possible between the species so produced. There are many questions about just how this process occurs despite the vast effort expended on its study. How do differences arise and become established? How are allopatry, sympatry, gene flow and selection involved? How do pre and post mating barriers establish?

These questions will be addressed using data from studies on hybrid zones in several insects and the considerable literature covering other organisms. The range of characters, numbers of genes, dynamics, evolution and systematic significance of these phenomena will be discussed. This will bear on some models of speciation and the extent of gene flow between taxa.

EVOLUTIONARY ASPECTS OF HYBRID DYSGENESIS IN *DROSOPHILA*. M.G. Kidwell, Department of Ecology and Evolutionary Biology, University of Arizona, Tucson, Arizona 85721, U.S.A.

Hybrid dysgenesis occurs as the result of destabilization of certain families of transposable elements following hybridization between genomes with different complements of elements. A temporary phase of genomic instability associated with high transposition frequencies is manifested at the phenotypic level in a variety of genetic traits including sterility, reduced viability, chromosomal aberrations and high mutation rates. Genomic stability is usually restored by element self-regulation.

Despite an associated reduction of fitness, the efficiency of transposition of active elements enables them to invade populations and species at inordinately high rates and also, given a suitable vector, allows the possibility of interspecific gene transfer. However, this invasive ability, together with the conditional and partial nature of the associated sterility seems likely to preclude a role for transposable elements in the development of reproductive isolation.

The main evolutionary significance of hybrid dysgenesis determinants may lie in their high efficiency as generalized or specialized mutators. A tendency to be activated by changing internal and external environmental conditions and an ability to insert preferentially in restricted genomic sites might provide especially significant sources of variability for evolutionary change.

POST-MATING BARRIERS TO GENE FLOW AMONG SPECIES OF TSETSE FLIES. R.H. Gooding, Department of Entomology, University of Alberta, Edmonton, Alberta, Canada T6G 2E3.

New data and a literature review are presented on hybridization of species and subspecies of *Glossina*. Within each subgenus, inter-taxon hybridization occurs readily in the laboratory and occasionally in the field. Genetics of hybridization is being studied in two groups: for *G. m. morsitans* / *G. m. centralis* / *G. m. submorsitans* lines marked on three chromosomes are being used; for *G. p. palpalis* / *G. p. gambiensis* lines carrying an X chromosome marker are being used. Under laboratory conditions there are no barriers to inter-subspecific mating and insemination. Post-mating barriers to gene flow between taxa include: 1) sterility of hybrid males, 2) low rates of intra-chromosomal recombination (particularly in the X chromosome) in hybrid females, 3) low fecundity of females mated with males from a different subspecies, and 4) low fecundity of hybrid females. Males are usually sterile if they have X and Y chromosomes from different taxa; exceptions occur among hybrids of *G. m. morsitans* / *G. m. submorsitans*. In those combinations where there is a marked asymmetry in the success of reciprocal inter-taxon crosses, uni-directional sterility of males is caused by maternally inherited (extra-chromosomal) factors. However these factors appear to be unstable and their effectiveness as barriers to gene flow declines after several generations of outcrossing. The genetic basis of lower fecundity of females is still being investigated.

SPECIATION AND INFECTIOUS HEREDITY IN THE *DROSOPHILA PAULISTORUM* COMPLEX.

Lee Ehrman* and N. Somerson, Division of Natural Sciences, State University at Purchase, Purchase, New York. Intracellular symbionts are common in the insect world, and all semispecies of the *Drosophila paulistorum* complex contain such cytoplasmic symbionts. These endosymbionts are injected into females of the Santa Marta, Transitional semispecies and the recipients mated five days later, the male progeny are sterile. Streptococcal L-Forms isolated from these semispecies can also induce the male sterility in transfers of L-Forms from one semispecies to another. In the present experiments, L-Forms isolated from Mesitas flies have been injected into both Mesitas and Santa Marta females. The flies were then mated (A) immediately; (B) after 24; or (C) 48 hours with males of their own semispecies. When Santa Marta females were mated within hours following injection of L-Forms isolated from Mesitas flies, practically all the male offspring were sterile. In contrast, the overwhelming majority of the male progeny from Mesita subjected to the same treatment possessed motile sperm. Again, when Santa Marta females were mated twenty-four hours after injection, the male offspring similarly treated Mesitas females had motile sperm. The same type of results were obtained with flies mated 48 hours after injection. However, the total progeny from Santa Marta flies was drastically reduced. In no case was the sex ratio affected. Male progeny from Mesitas or Santa Marta flies injected with a sterile sucrose solution possessed normal sperm. Females mated with these sons showed evidence of insemination. These data confirm the specificity in the action of the L-Forms isolated from the Mesitas flies. More importantly, they show that results from matings at 0, 1, or 2 days after injections are consistent with those obtained in injections of extracts of flies and matings five days later.

ACOUSTIC RECOGNITION SIGNALS AND SPECIES ISOLATING MECHANISMS IN HOMOPTERA: AUCHENORRHYNCHA.

M.F. Claridge, Department of Zoology, University College, Cardiff, CF11XL, Wales, U.K.

Substrate transmitted acoustic signals are major elements of the specific mate recognition systems of leafhoppers and planthoppers and thus also function as species isolating mechanisms. Geographical variation in calls of species of *Nilaparvata* from Asia and Australasia will be documented. Pulse repetition frequencies (PRF) of male and female calls vary between populations. Differences in PRF are major barriers to hybridisation between related populations, despite a lack of obvious postmating barriers.

SPECIATION BY HYBRIDIZATION IN PHASMIDS AND OTHER INSECTS. L.Bullini* and G.Nascetti, Department of Genetics and Molecular Biology, University of Rome "La Sapienza", via Lancisi 29, Rome, Italy.

Genetic studies have shown that several all-female insect species originated by interspecific hybridization. A number of such cases are reviewed, with special emphasis on stick-insects (Phasmatodea). Insect hybrid species reproduce by thelytokous parthenogenesis (in some cases by gynogenesis) and can be either diploid or polyploid. Their level of heterozygosity is generally high, and related to the genetic divergence of the parental species. The number of biotypes observed vary greatly among hybrid species, from a few to several hundreds.

The processes involved in the origin of insect hybridogens are discussed, e.g. the changes in the maturation divisions that allow the transmission of the hybrid genome to the next generation. Two phenomena are considered particularly relevant for the evolutionary success of a hybrid insect species: 1) their reproductive potential, doubled with respect to that of their bisexual ancestors ("demographic advantage"); 2) their heterozygosity, dramatically enhanced by interspecific hybridization ("heterotic advantage").

CONTRASTING PATTERNS OF GENE FLOW & INTROGRESSION ACROSS A NARROW HYBRID ZONE: NUCLEAR AND CYTOPLASMIC INDEPENDENCE? D. Shaw*, A. Marchant, M. Arnold and B. Kohlmann, Population Genetics, RSBS, ANU, Canberra, ACT, 2601, Australia.

Narrow hybrid zones between chromosomally different but closely related taxa have been described in a variety of orthopteroid insects. Despite implications that the chromosomal rearrangements act as primary mechanisms in maintaining the zones, empirical support is lacking. Using molecular, biochemical and cytological techniques to generate an array of cytoplasmic and nuclear markers, we present evidence to indicate that the hybrid zone in *Caledia captiva* represents a dynamic interaction between 2 differently adapted cytotypes. Moreover, the chromosome rearrangements that distinguish them are primarily responsible for maintaining the zone and represent adaptations to contrasting environments. The zone has moved during the recent past leaving behind a series of neutral markers up to 400km beyond its present location while still retaining its very narrow chromosomal profile (<1km). Estimates of ecological tolerances reveal that the current location of the hybrid zone coincides with a region of environmental overlap which is asymmetrical. Inter- and intra-taxon variation in phenology indicate that chromosome structure *per se* may be directly involved in adjusting the timing of developmental processes according to seasonality.

INTROGRESSIVE HYBRIDIZATION IN PONDSKATERS (GERRIDAE). J. R. Spence, Department of Entomology, University of Alberta, Edmonton, Alberta, Canada T6G 2E3

Two *Limnopus* species hybridize extensively where they co-occur in western Canada. Despite elaborate mating behavior, there is no evidence for pre-mating isolation, and interspecific matings are commonly observed in the field between *L. notabilis* females and *L. dissortis* males. Size and behavioral constraints suggest that the reciprocal pairing is unlikely under field conditions although it is easily obtained in the laboratory. Individuals of *L. dissortis* from Alberta and Quebec are fully fertile, while individuals from both areas suffer a 50% reduction in hatch of fertile eggs when mated reciprocally with *L. notabilis* from British Columbia. F₁ hybrids are males which are viable, fully fertile and produce progeny of both sexes when backcrossed to the maternal species. If backcrossed to the paternal species, only male progeny are produced. Both species have ten autosomes and an XO system of sex chromosomes with males heterogametic, suggesting incompatibility of X chromosomes between species as an explanation of the breeding data. There are significant frequency differences between pure populations of the species at seven electrophoretic loci. Studies of populations spanning the hybrid zone provide evidence for introgression at autosomal loci but show that there is no exchange at a sex-linked locus. Extensive genetic exchange between these two species, thought not to be sister taxa, emphasizes the probable importance of reticulations in phylogeny of semiaquatic bugs.

HYBRIDIZATION IN NATURAL POPULATIONS OF GROUND-BEETLES (COLEOPTERA: CARABIDAE). D. Mossakowski, Department of Biology, University of Bremen, NW 2, D-2800 Bremen 33, FRG.

This study analyses ecological, morphological, and biochemical data regarding the two species *Carabus lineatus* and *C. splendens* which have reduced hind wings.

There are three special features of this example of a hybrid zone: (i) The width of the zone is about 120 km. The zone of overlap and hybridization occurs in the Pyrenees, South-West of France, and in the adjacent regions of North-Eastern Spain. (ii) There exist small ecological differences and restrictions in the reproduction of the F₁-generation. (iii) The hybrids may be more easily distinguished by single characters or multivariate discriminant analysis than by electromorphs. This depends on sex-linked inheritance and a polymorphism in gene numbers in those characters which differ between the species.

A hypothesis is developed which makes it possible to understand such broad hybrid zones as a particular case of small hybrid zones.

HYBRID POPULATIONS IN *PAPILIO* BUTTERFLIES. F.A.H. Sperling, Ecology and Systematics, Cornell University, Ithaca, NY, USA, 14853

Species of the *Papilio machaon* complex hybridize extensively in some regions of western Canada. Hybrid populations are composed of genes from up to three species, and show unimodal phenotypic distributions with no interruptions in gene flow. The parental species interact elsewhere with little hybridization. Formation of hybrid populations is related to degree of ecological divergence of populations prior to secondary contact, and predates human-related habitat disturbance. Interspecific hybridization has led to persistent polymorphism within the *P. machaon* complex, and may be implicated in speciation in other butterflies. The importance of hybrid interactions has probably been greatly underestimated in butterfly taxonomy, both at the species level and higher.

NATURAL HYBRIDIZATION IN *DROSOPHILA* WITH SPECIAL REFERENCE TO SPECIES FROM HAWAII. K. Y. Kaneshiro, Hawaiian Evolutionary Biology Program, University of Hawaii, Honolulu, Hawaii 96822.

The few documented cases of natural hybridization in *Drosophila* species will be reviewed briefly. Evidence for introgression between pairs of species especially between *pseudoobscura* and *persimilis* and between two pairs of Hawaiian *Drosophila*, *heteroneura* and *silvestris* and *setosimentum* and *ochrobasis*, will be discussed. At least between *heteroneura* and *silvestris*, gene flow appears to be unidirectional based on morphological data. A hypothesis on the dynamics of the sexual selection process within these species will be presented to explain the asymmetrical mate preference between *heteroneura* and *silvestris* which may provide partial explanation for the unidirectional gene flow. The high genetic similarity between these species may be the result of present and/or past introgressive hybridization in sympatric populations.

SEX RATIO AND GROUP SELECTION IN PARASITIC HYMENOPTERA. L.P. Nunnery, Department of Biology, University of California, Riverside, Ca 92521, USA.

It was recently suggested that the female-biased sex ratios so ubiquitous in the parasitic Hymenoptera arise in response to group selection, because producing such a sex ratio is individually disadvantageous. This viewpoint can be countered by the demonstration that a maternal wasp is actually maximizing her individual fitness through "local parental control" (LPC) of the mating success of her offspring. The concept of LPC can be used to understand the involvement of local mate competition and sib mating in the expected sex ratio bias; furthermore, it provides a way of predicting the sex ratio bias when additional features of particular wasp breeding systems are incorporated. In many systems nearby females may breed asynchronously and males may disperse in search of mates. Both of these features can have an important effect upon the expected sex ratio.

SEX DISTORTING EXTRANUCLEAR FACTORS. John H. Werren, Department of Biology, University of Rochester, Rochester, New York 14627.

A wide range of unusual genetic elements (including inherited microorganisms) alter sex determination and sex ratios in insects. Some of these cause all-female families, while others cause male specific lethality or all-male families. The distribution of such sex distorters in insects, and the evolution, is discussed. In addition, the remarkable wasp *Nasonia vitripennis*, is described. Finally, the significant possibilities of utilizing sex distorters in insects biological control is explored. Applied research into this area could be quite fruitful.

SEX RATIO AND CLUTCH SIZE PROBLEMS WHEN MASS-REARING PARASITIC HYMENOPTERA. H.C.J. Godfray* and J.K. Waage, Department of Pure and Applied Biology, Imperial College and C.A.B. International Institute of Biological Control, Silwood Park, Ascot, Berkshire SL5 7PY, United Kingdom.

The mass-rearing of parasitic wasps as part of biological control programmes often fails through a breakdown in the reproductive behaviour of the wasp. Examples of this are the common tendency for cultures to become highly male-biased or for excessive superparasitism to reduce the survival of the wasps. In our talk we discuss examples of, and the causes of this aberrant behaviour, and examine the contribution that population biology can make to reducing these problems.

VARIATION IN FITNESS: GENDER ALLOCATION BASED ON HOST SIZE. R.F. Luck* & D.S. Yu, Department of Entomology, University of California, Riverside, California 92521, USA.

Most parasitic Hymenoptera control the gender of an offspring by controlling whether or not an egg is fertilized at the time of oviposition. Those parasitoids that lay their eggs in pupae or eggs, or that paralyze the host at the time of oviposition, can assess the amount of resource available for their progeny's development and allocate offspring accordingly. Frequently such species allocate male offspring to the smaller hosts and female offspring to larger hosts. Theory suggests that they should do so when small daughters, relative to their larger sisters, lose more fitness than do small sons, relative to their larger brothers. The predictions of this theory will be discussed and evaluated with available data, along with its implications for the dynamics of a host-parasitoid interaction.

PSEUDO-ARRHENOTOKY DOES NOT PRECLUDE SEX RATIO CONTROL: A TEST USING PHYTOSEIID MITES AND ITS EVOLUTIONARY IMPLICATIONS

M.W. Sabelis* and C.J. Nagelkerke

In arrhenotokous arthropods males arise from unfertilized eggs. Hence, by controlling the fertilization process mothers can adjust the sex ratio in their progeny. In pseudo-arrhenotokous phytoseiid mites males are haploid, but arise from fertilized eggs. The haploid state is achieved through elimination of the paternal chromosome. It was found that phytoseiid females can control the sex ratio of their offspring and that this control seems as flexible as as in arrhenotokous arthropods. As expected from sex allocation theory sex ratios approached half son half daughters under random mating, whereas a female bias was found with increasing probability of sib-mating. The importance of these results for understanding the adaptive significance of pseudo-arrhenotoky are discussed.

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A NEW POLYCHROMATIC TECHNIQUE FOR INSECT GENOME ANALYSES.
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State University, Bowling Green, Ohio 43403, USA.

In recent years, there have been several developments in various techniques, such as chromosome banding, for the detection of gene or chromosomal rearrangements. However, due to limited resolution and identification of genes (bands) many problems still remain, since all of the available techniques have been monochromatic. Our longtime attempts to develop a new polychromatic technique have been achieved very recently (Yoon, 1986). This new polychromatic technique will significantly increase our capacity to analyze the rearrangements of genes and chromosomes, as well as to distinguish the evolutionary relationships of the genes for closely related species. This technique will be most advantageous for studies of cytogenetics, phylogenetics and gene regulation in general. Furthermore, this technique is very useful to detect single allelic change(s) in polytene chromosomes, and also to distinguish the paternal and maternal genes and chromosomes. Further development and applications of this new technique will be an invaluable advance not only for Dipteran genetics, but also for mammalian and human genetics. (Supported in part by U.S. NSF grant BSR-8400615).

POLYTENE CHROMOSOMES IN ADULT TSETSE FLIES (DIPTERA, GLOSSINIDAE) AND A NEW TOOL FOR THEIR STUDY. P. Elsen, Laboratory of Entomology, Institute for Tropical Medicine, 155 Nationalestraat, B-2000 Antwerp, Belgium.

Polytene chromosomes in Glossina (Diptera) have been discovered up to now only in pupae 36 to 48 hours old (in muscles tissues) or 17 to 19 days old (in trichogene and thormogene cells of thoracic bristles). Their discovery in adult flies of any age allows a direct genetic identification of flies freshly caught in the field without having to breed them to get pupae of suitable age. The first results obtained on Glossina morsitans morsitans are exposed and discussed.

On the other hand, a new method of analysing polytene chromosomes in general by image analysis on computer is exposed. It allows one to obtain straight images of such chromosomes, a parallel curve of optical density of DNA in each band of those chromosomes and a comparison of these images to those put in memory as standard references.

EVALUATING AND ANALYZING P ELEMENT FUNCTIONALITY IN INSECTS. D.A. O'Brochta, USDA/ARS, Gainesville, Florida 32604

As part of an effort to develop gene transfer methods for insects of medical and economic importance the mobility of the transposable element P from Drosophila melanogaster was assessed in non-drosophilids. P elements were mobilized in Paralimna decipiens (family: Ephydriidae), but not in Borborillus frugipennis (family: Sphaeroceridae) or Anastrepha suspensa (family: Tephritidae). Thus P element mobility is phylogenetically restricted and without modifications these transposable elements will not be useful as general insect gene vectors. Possible reasons for this restriction are discussed as well as alternative gene transfer strategies.

THE SEARCH FOR TRANSPOSABLE ELEMENTS IN THE MALARIA VECTOR ANOPHELES GAMBIAE. Rebecca Reiss*, Ross MacIntyre, Department of Genetics, and Henry Hagedorn, Department of Entomology, Cornell University, Ithaca, NY 14853.

The aim of this project is to identify mobile genetic elements that could be used to develop a transformation system in the mosquito. Three different strategies have been used to isolate DNA fragments that are repetitive, have different copy numbers in different strains, and have different genomic locations. First, clones from a lambda bacteriophage library were randomly selected and hybridized to genomic southern blots of DNA from different strains. To enrich for repetitive sequences, our second strategy was to hybridize duplicate filters lifts to different nick translated whole genomic DNA from different species, and isolate those plaques that exhibited different signals. The final strategy was to isolate a gene and its mutant alleles and survey the region for repetitive elements. DNA homologous to the Drosophila white eye locus has been isolated from wild-type and mutant-eyed strains of An. gambiae, and is currently under investigation.

MICROPIA-ELEMENTS: A NEW RETROTRANSPOSON-LIKE SEQUENCE FAMILY IS Y-CHROMOSOME ASSOCIATED AND HIGHLY CONSERVED BETWEEN DROSOPHILA MELANOGASTER AND DROSOPHILA HYDEI. D.-H. Lankenau*, P. Huijser and W. Hennig, Dpt. of Molec. and Devel. Genetics, University of Nijmegen, Toernooiveld, 6525 ED Nijmegen, The Netherlands

The Y-chromosomal lampbrush loops 'Threads' of primary spermatocytes of D. hydei have been microdissected and cloned in a lambda-vector. Two of the recombinant clones are homologous to clones from a Charon 4A genome bank of D. melanogaster. Screening the DNA sequences of such clones from D. hydei and D. melanogaster with the EMBL-Genebank sequence collection revealed homology to CaMV (Cauliflower mosaic virus), TMV (Tobacco vein mottling virus), TMV (Tobacco mosaic virus), Ty-elements of yeast, the Drosophila copia-like element 17.6 and other retroviruses such as the chicken RSV (Rous sarcoma virus) or the primate AIDS viruses. This homology reflects the presence of a nucleic acid-binding protein homologous to the 'finger' domain of p15 in AIDS viruses, a protease-, a reverse transcriptase-, RNase- and an integrase-like coding sequence in a new family of transposable elements within the genus Drosophila called MICROPIA-family.

Members of this family are located and expressed within Y-chromosomal fertility factors.

MOLECULAR GENETICS OF A METHOPRENE-RESISTANCE GENE IN DROSOPHILA MELANOGASTER. T.G. Wilson, C. Turner and L. Shemshedini, Department of Zoology, University of Vermont, Burlington, VT 05405, USA.

Methoprene, a juvenile hormone (JH) analogue, is a potent insecticide against dipteran insects. We have used methoprene to select resistant Drosophila and have identified a locus, Methoprene-tolerant (Met), that results in nearly 100-fold resistance to methoprene or JH III. Various mutagenizing agents, including P-element transposable elements, have been used to produce a collection of eleven Met alleles. The genetic location and phenotype of Met has been examined in detail. Physiological experiments with radiolabelled JH III as well as genetic studies suggest target-site insensitivity. Insertion of a P element into or near the Met gene has been confirmed by in situ hybridization for one of the P element alleles. This allele will be used to clone the Met gene by the transposon-tagging method.

GENOME SIZE AND EVOLUTION IN CHRYSOMELIDAE (COLEOPTERA). E. Petitpierre*, C. Juan and C. Segarra, Lab. Genetica, Dep. Biologia, 07071 Palma de Mallorca (Spain), and Dep. Genetica, Fac. Biologia, 08028 Barcelona (Spain).

Microdensitometric measures of Feulgen-stained spermatids in twenty-four species of leaf beetles have been undertaken using Tribolium castaneum as standard species. The DNA contents (pg) were as follows: Crioceris asparagi 0.70, C. 12-punctata 0.40 (Criocerinae), Lachnala vicina 0.25, Coptocephala floralis 0.40 (Clytrinae), Timarcha balearica 0.91, Chrysolina americana 0.56, C. banksi 1.17, C. peregrina 1.07, Gastrophysa polygoni 0.35, Phaedon cochleariae 0.52, Chrysomela populi 0.35, Prasocuris junci 0.20 (Chrysomelinae), Ophraella communa 0.60, O. cribrata 1.36, Xanthogaleruca luteola 0.36 (Galerucinae), Longitarsus succineus 1.33, Aphthona flavipes 0.46, A. lutescens 0.87, Crepidocera plutus 0.24, Chaetocnema chlorophana 0.56, Podagrica fuscicornis 1.98, Sphaeroderma testaceum 1.79 (Alticinae), Dicladispa testacea 0.62 (Hispidinae), and Cassida vittata 1.61 (Cassidinae). Therefore, the range is almost tenfold but it is not in correspondence with the chromosome numbers, which show the highest heterogeneity among beetle families. We have only found in the Chrysomelinae a possible interrelationship between increases in the modal diploid numbers and a decrease in the DNA content of spermatids.

GENETIC STUDIES OF CULICOIDES VARIIPENNIS. W.J. Tabachnick, USDA, Agricultural Research Service, Arthropod-borne Animal Diseases Research Laboratory, P.O. Box 3965, Laramie, Wyoming, USA 82071.

Culicoides variipennis is the primary vector of bluetongue virus in North America. The genetic structure of the species is virtually unknown. Eighteen isozyme genetic loci have been analyzed for electrophoretic variation to determine the extent of genetic variation in three long established laboratory colonies of C. variipennis as well as several natural populations. Genetic heterogeneity as indicated by average expected heterozygosity of the laboratory colonies is comparable to natural populations of other insect species. Field populations of C. variipennis possess considerably higher levels of genetic variation. The significance of this variation and implications for future studies concerning the role of this species as a vector of disease will be discussed.

THE GENETICS OF A COLONIZING SPECIES: Aedes albopictus (SKUSE) IN THE UNITED STATES. Srinivas Kambhampati*, William C. Black IV and Karamjit S. Rai, Department of Biology, University of Notre Dame, Notre Dame, IN 46556 USA

The recent (1935) introduction of a medically important mosquito, Aedes albopictus, into the U.S. provides a unique opportunity to study the genetics of colonization of a species during the process of colonization. In our previous studies, genetic changes that have accompanied the establishment of Ae. albopictus in the U.S. were described. These studies have shown that (i) the probable origin of the U.S. populations is temperate Japan; (ii) much genetic drift has accompanied their establishment in the U.S.; and (iii) considerable variation exists within and between U.S. populations as measured by both isozyme loci and size of non-transcribing spacer of ribosomal DNA. Subsequent studies were aimed at monitoring spatial and temporal changes in allelic frequencies in the period following the establishment of Ae. albopictus, because such changes may influence the long-term establishment and spread of a colonizing species. In this paper, we report on changes in frequencies of isozyme loci and rDNA spacer length that have occurred during the second year following establishment in several populations of Ae. albopictus in and around Houston, Texas. (Supported by NIH grant AI 21443 to KSR)

WITHIN- AND BETWEEN-POPULATION GENETIC DIVERSITY OF SEXUALS AND CLONES, IN THE PSEUDOGAMOUS BARK BEETLE *IPS ACUMINATUS*. L.R. Kirkendall*, J. Kaukinen, A. Saura and J. Lokki, Zoology Division, Univ. Oslo, Box 1050 Blindern, N-0316 Oslo 3, NORWAY.

Ips acuminatus populations are composed of sexuals and sperm-dependent clones. More than 50 populations have been analysed electrophoretically, from Norway, Sweden, Finland, and Bulgaria. Many clones have been identified, but one or a few dominate any given population. The nature of the genotypes and their distributions suggest that clonal diversity arises from both multiple origins of clonal lineages and mutation within lineages. Gene flow among sexuals is high enough to prevent population differentiation. However, the clones present and their relative frequencies differ considerably among populations, suggesting that either the clones are under strong local selection or arise and go extinct rapidly. The implications of these results for models for the maintenance of sex are discussed.

A POSSIBLE ROLE OF MACROMUTATIONS IN THE MACROEVOLUTION: A CASE STUDY IN TENEBRIONIDAE (COLEOPTERA). S. Endrödy-Younga, Transvaal Museum, PO Box 413, Pretoria, 0001, Republic of South Africa.

The observed morphological diversity in extant groups of Coleoptera differs between families. It might be minimal (Gyrinidae, Scaphidiidae), or extensive (Scarabaeidae, Tenebrionidae). In the Tenebrionidae the diversity reaches its extreme in the subfamily Tentyriinae. The diverse tribes of Tentyriinae are restricted to southern Africa suggesting the post-Gondwana origin of gross diversification in time. Thus, there has been hardly enough time for a finely graded evolution leading to them.

Recently, three species of the tribe Cryptochilini were found whose males are very similar to a sympatric species of the genus *Cryptochile*, whereas their females could hardly be recognized as tenebrionids.

If the suspected mutation affected both sexes simultaneously, these species could have been recognized as a further major evolutionary division in the family. If such mutations could bridge the morphological gaps between many tentyroid tribes in abrupt evolutionary leaps, an infinitely high number of extinctions need not be postulated during the limited period of evolutionary time available for them.

HETEROGENEITY, HETEROZYGOSITY AND HETEROSIS IN *PAPILIO GLAUCUS*: EVIDENCE FROM LABORATORY HYBRID STUDIES.

J. Bossart and J. M. Scriber, Department of Entomology, Michigan State University, East Lansing, Michigan. 48824

Protein heterozygosity found among various populations of the tiger swallowtail butterfly, *Papilio glaucus*, appears to be especially prominent in the Great Lakes region near the geographic juncture of two subspecies (*P.g. glaucus* and *P.g. canadensis*). We have been interested in determining the extent of interbreeding across this hybrid zone and the ecological implications of subspecies interactions.

In addition to nearly fixed allozyme differences, it is also known that significant differences in foodplant detoxication abilities, adult morpho-metric features, color polymorphisms, color suppression and diapause physiology exist between the two subspecies. These differences have a genetic basis. With the use of hand-pairing techniques we have been able to hybridize and backcross various *Papilio* taxa. This permits us to investigate the degree to which natural protein heterozygosity could be due to introgression between these two subspecies across the hybrid zone. In addition, we are investigating the correlation of protein heterozygosity and larval growth rate in various natural populations (including hybrid zone) and in various laboratory hybrids.

TRANSMISSION OF HEREDITARY TRAITS OF *T. CASTANEUM* (HERBST) TO *T. CASTANEUM*-*T. FREEMANI* HYBRIDS (COLEOPTERA: TENEBRIONIDAE). Aaron Brownlee and Alexander Sokoloff*, Biology Department, California State University, San Bernardino, California 92407.

Tribolium freemani Hinton is a very close sibling species of *T. castaneum* (Herbst). When these species are crossed in reciprocal matings they produce abundant progeny all of which are sterile. We have utilized sex-linked recessive mutants, and autosomal semidominant and dominant morphological, body color and eye color mutants, as well as two mutants which control quantitative traits to determine to what extent the mutants recovered in the hybrids resemble the phenotype of mutants recovered when intra-species crosses between wild type and mutant strains are performed. All of the mutants tested produced the same phenotypes and ratios in *T. castaneum*-*T. freemani* crosses as they did when *T. castaneum* wild type and mutant strains were crossed. The significance of these results will be discussed.

INHERITANCE OF FERTILITY COMPONENTS IN THE MIGRATORY GRASSHOPPER, *MELANOPLUS SANGUINIPES*. W. Chapco, Department of Biology, University of Regina, Regina, Saskatchewan, Canada S4S 0A2.

Parental crosses, hybrid crosses and backcrosses involving a nondiapausing strain of *Melanoplus sanguinipes* and strains derived from populations representing subspecies *sanguinipes* (from British Columbia, Saskatchewan and Quebec), *vulturinus* (from Louisiana and Texas), and *defectus* (from Arizona) yielded measurements of a number of fertility components, including fecundity, egg hatchability and time-to-hatch. Despite the great distances separating some of the populations, there was no evidence of post-reproductive isolation in the form of inviability or sterility. Standard statistical analysis revealed significant generational differences with little evidence of hybrid vigor as in *Drosophila* studies. The results of detailed "Mather-Jinks" genetic analyses indicate that while complex genic interactions are present (e.g. triple homozygous interaction), certain general patterns are evident. A grandmaternal factor, for example, significantly influences egg hatchability. Fecundity is not only a function of the maternal genotype, the level of production is affected by paternal genotype.

HYBRIDIZATION AND CHROMOSOMAL BASIS OF RADIATION IN *DROSOPHILA*. H.A.Ranganath & N.B.Ramachandra, Department of Zoology, University of Mysore, Manasagangotri, Mysore 570006, INDIA.

Drosophila nasuta nasuta (2n=8) and *D.n. albomicana* (2n=6), a pair of cross fertile races, have conspicuous karyotypic divergence & symptoms of post-mating isolating mechanisms. Hybridization of these races followed by hybrid maintenance & hybrid recombination has resulted in the evolution of two new novel races referred to as Cytorange I (males 2n=7; females 2n=6) and Cytorange II (males and females 2n=6). The karyotypes of these Cytoranges are new in composition and each one of them have inherited chromosomes from both the parents. In a way, in this instance, hybridization has acted as an 'evolutionary catalyst' and the sequence of events which led to the evolution of Cytoranges fits into the 'transilience mode of speciation' proposed by Templeton (1981). The implications of these findings will be discussed.

SEX-RATIO STUDIES IN *EPIDINOCARSIS LOPEZI* (HYMENOPTERA: ENCYRTIDAE), A PARASITOID OF THE CASSAVA MEALYBUG, *PHENACOCCLUS MANIHOTI* (HOMOPTERA: PSEUDOCOCCIDAE). M.J. van Dijken* and J.J.M. van Alphen, Department of Population Biology, University of Leiden, P.O. Box 9516, 2300 RA Leiden, The Netherlands.

E. lopezi is used as a biological control agent against the cassava mealybug, *P. manihoti*, a serious pest of cassava in Africa. Because female parasitoids attack the mealybugs, efficiency of parasitoid mass rearing is maximized when maximum numbers of healthy female wasps can be obtained. Therefore studies were undertaken in our laboratory to determine the mechanisms influencing sex ratio in *E. lopezi*. Potential factors affecting sex ratio are: (1) local mate competition, (2) shifts in sex ratio due to host quality aspects, (3) differential survival of the sexes in either small hosts or in superparasitized hosts containing eggs of both sexes. We explain why local mate competition does not play a role in this species, and show that differential survival in superparasitized hosts does not affect sex ratio. Biased sex ratios can therefore only be caused by shifts in sex ratio in response to host size. This view is supported by the observation that *E. lopezi* lays haploid (male) eggs in small hosts and diploid (female) eggs in larger hosts.

ADAPTIVE SEX RATIO VARIATION IN APHIDS. N. A. Moran, Department of Entomology, University of Arizona, Tucson, AZ. 85721.

Due to their parthenogenetic mechanism for producing the sexual generation, aphids show maternal control of offspring sex and thus provide opportunities to test evolutionary sex ratio theory in diploid organisms. In the Pemphiginae, sexuals frequently occur under conditions favoring male biases due to local mate competition. Comparative data on the development and magnitude of such biases are presented for several species. In the Aphidinae, the benefits of male and female production depend on characteristics of the host plant which correspond to its future favorability for descendant clones. Data are presented which show an influence of host status and host taxon on the sex ratio of aphidine colonies. The pattern of production of the sexuals shown by host-alternating Aphidinae is hypothesized to be a consequence of a pre-existing ability for adaptive sex ratio control in response to host characteristics.

SEX ALLOCATION, LARVAL HOST EXPLOITATION AND BODY SIZE OF THE COCKROACH HUNTING WASP *AMPULEX COMPRESSA* (FABR.) STUDIED UPON FOUR DIFFERENT PREY SPECIES (HYMENOPTERA: SPHECIDAE: AMPULICINAE, DICTYOPTERA: BLATTIDAE). Wijnand R.B. Heitmans, Laboratory of Experimental Entomology, University of Amsterdam, Kruislaan 302, 1098 SM Amsterdam, The Netherlands.

A. compressa females attack the last five nymphal stages and adults of several cockroach species all belonging to the family of the Blattidae. They lay one egg per captured prey.

The sex ratios in the wasp's progeny vary on different stages of development of the prey and are controlled by the mother wasp. Except for the maternal decision to produce exclusively sons on small preys and an increasing number of daughters towards a defined optimum on larger hosts, a different utilization of the food source by male and female larvae of the wasp tremendously influences the ultimate size of the offspring. This means, that female wasps are always larger than males, when reared on the same type of prey. The aim of the study was to understand the adaptability of the variation in sex allocation of individual wasps, since fitness-parameters in female Hymenoptera often appear to be a function of body size—large body size positively affects reproductive success—, whereas in males such a relation is less direct.

PROXIMATE INTERNAL FACTORS CONTROLLING SEX RATIO IN PARASITOID WASPS. F.A. Putters* and J. van den Assem, Department of Zoology, Div. of Ethology, University of Leiden, P.O.Box 9516, 2300 RA Leiden, The Netherlands.

In several species of parasitoid wasps, the physiological mechanism which governs egg laying also appears to be the basic determinant of sex ratio. This can be inferred from detailed measurements of oviposition behaviour. These results confirm in a direct way the existence of adaptations which have been predicted by sex-ratio theory.

Parasitoid wasps adjust their offspring sex-ratios to characteristics of the host population on which they operate. The remarkable achievements are not the exclusive effects of the actual, external stimulus situation; earlier experience plays a role as well. Quantitative tests of sex-ratio models were never adequately controlled in this respect, and have shown a lot of unexplained variance. Physiological variables associated with the process of egg maturation appear to provide an adequate alternative for a complex, internal model which is supposed to represent the relevant aspects of the host population.

EFFECTS OF LARVAL COMPETITION UPON THE VARIATION OF SEXUAL RATIO IN *DIADROMUS PULCHELLUS* (ICHNEUMONIDAE). D. Rojas-Rousse, V. Labeyrie*, IBEAS, UA CNRS 340, Université de Pau 64000 Pau, France.

D. pulchellus females lay an egg in each oviposition. Supervising oviposition in each host allows to know the rank of the egg laid during consecutive ovipositions.

Without larval competition, the growth of a virgin female's offspring is independent of the egg's rank during consecutive ovipositions; larval mortality and adult appearance are hazardous phenomena. For an inseminated female, viability of diploid eggs is significantly superior to that of haploid eggs. Frequencies distribution separates three lots of females: a) with a maximal production of daughters, b) with a minimum production of daughters, c) with a continuous variation in the number of daughters.

With larval competition, struggle between two haploid larva slightly increases nymphal mortality. A struggle between haploid larva (male) and diploid larva (female) always ends up in the elimination of the haploid larva.

Larval competition may be advantageous, by re-introducing selective pressures during the endoparasitismal life of larvae.

VARIATION OF THE PRIMARY SEX RATIO IN RESPONSE TO HOST SIZE IN THE APHID PARASITOID *EPHEDRUS CALIFORNICUS*.

Cloutier, C. Département de Biologie, Université Laval, Sainte-Foy, Québec, Canada G1K 7P4, A. Lévesque, and M. Mackauer, Department of Biological Sciences, and D. Eaves, Department of Mathematics and Statistics, Simon Fraser University, Burnaby, British Columbia, Canada, V5A 1S6.

Variation in the primary sex ratio was examined experimentally by fitting logistic regression models to data on sex of offspring from mated females. The method used data on the progeny sex ratio at the time of adult emergence, and an independent estimate of male juvenile mortality fitted from emergence data of the (exclusively male) progeny of virgin females. Mated female *Ephedrus californicus* responded to small pea aphids hosts, *Acyrtosiphon pisum* (Harris), by laying significantly less fertilized eggs than in large ones. The response had a strong individual component and its flexibility was revealed by the significance of covariables related to the previous experience of parasitoids with hosts of different sizes. The results suggest that asymmetrical allocation of host resources to sons and daughters may have selective advantage even in the case of parasitoids developing in growing hosts such as aphids nymphs, where the amount of resource available to the parasitoid's progeny is not fully predictable at the time of oviposition.

DISTRIBUTION OF HETEROCHROMATIN IN THE SARCO-PHAGID POLYTENE SYSTEM (DIPTERA). U.R. Agrawal*, R.R. Tewari and D. Kaul, Department of Zoology, University of Allahabad, Allahabad-211002, India.

Polytene chromosomes of pupal foot pad cells of flesh flies *Parasarcophaga ruficornis*, *P. argyrostoma*, *P. knabi*, *P. albiceps*, *P. orchidea* and *P. misera* were studied following C-banding and staining with fluorochromes-quinacrine dihydrochloride, Hoechst 33258 and acridine orange. The salient sites of heterochromatin distribution are :

- i) Region 6A of chromosome II and 3B-4A of chromosome V where most of the species show variable amounts of heterochromatin in the form of bands or blocks,
- ii) The granules of the heterochromatic mass which correspond to the mitotic sex chromosomes.

P. misera is a unique species in which negligible heterochromatin is present and neither heterochromatic granules nor banded polytene sex elements are traceable in the polytene nuclei.

These findings have been compared with the distribution of heterochromatin in the mitotic chromosomes.

INTERCHROMOSOMAL EFFECT ON RECOMBINATION BETWEEN LINKED INVERSIONS IN *DROSOPHILA ANANASSAE*.

B.N. Singh and A.K. Singh, Department of Zoology, Banaras Hindu University, Varanasi 221 005, India.

In *Drosophila ananassae*, two linked inversions located in the opposite limbs of the third chromosome are of common occurrence in natural populations as well as in laboratory stocks. By utilising different stocks homozygous for the standard or inverted gene sequences in the second and third chromosomes, the rate of recombination between linked inversions when heterozygous was studied under different karyotypic backgrounds by means of the salivary gland smear technique. In spite of the long chromosome distance between the two inversions, the crossover rate is very low and it varies in different strains. Furthermore, there is a considerable increase of recombination between heterozygous inversions due to inversion heterozygosity in 2L indicating inter-chromosomal effect. These findings provide evidence that recombination between linked inversions in *D. ananassae* is influenced by background karyotype and background genotype.

#2

AN UNUSUAL GENE THAT GIVES RISE TO ALL-MALE FAMILIES IN *NASONIA VITRIPENNIS* (HYMENOPTERA): CAN IT DRIVE POPULATIONS TO EXTINCTION? Leo W. Beukeboom & John H. Werren, Dept. Biology, Univ. Rochester, Rochester, NY 14627, USA.

Paternal sex ratio (psr) is a supernumerary chromosome in the parasitoid wasp *Nasonia vitripennis* that is paternally inherited and causes the production of all-male families. Normally, males are derived from unfertilized (haploid) eggs and females from fertilized (diploid) eggs. Psr is transmitted through the sperm and causes destruction of the paternal chromosomes, turning fertilized eggs into haploid eggs. The presence of psr can be detected with DNA specific probes for the psr chromosome. On first sight, psr is expected to drive populations to extinction, because no females are produced. A model was constructed to examine the influence of fertilization rate and population structure on psr frequency. Its predictions were experimentally tested using strains of *N. vitripennis* that differ in fertilization rate and by establishing populations consisting of different deme sizes. The psr frequency was determined each generation using the DNA probe. The Local Mate Competition (LMC) and extinction of local demes that occur when deme size is small causes a decrease in psr frequency in the population as a whole. In large demes where LMC is absent, extinction of total populations can occur when fertilization rate is high.

#3

THE USE OF ELECTROPHORETIC TECHNIQUES IN THE SYSTEMATICS AND POPULATION GENETICS OF THE GENUS *LIPARA* (DIPTERA, CHLOROPIDAE). L. De Bruyn, Laboratorium voor Algemene Dierkunde, Rijksuniversitair Centrum Antwerpen, Groenenborgerlaan 171, B-2020 Antwerpen, Belgium.

The species of the genus *Lipara* Meigen are monophagous parasites of the common reed, *Phragmites australis*. Recently, a systematic and population genetic study of this genus was started whereby we evaluated the possible use of polyacrylamide gel electrophoresis (PAGE) and isoelectric focusing (IEF).

Before electrophoresis, adult flies or larvae were completely homogenised in a 20% (w/v) aqueous sucrose solution. After homogenisation, samples were centrifuged at 15000 r.p.m. for 40 min at 4°C. PAGE was performed in homogeneous, vertically suspended gels (gel strength 6%). 3-6 µl supernatants of each sample was applied in individual wells on top of the gel. IEF was carried out in horizontal 1% agarose gels with a 4-6.5 pH gradient. 6 µl supernatants was applied in the wells nearly half-way between both electrodes. Gels were stained for general proteins.

25 enzyme systems have been investigated with PAGE, 18 of which gave scorable results. The intra- and interspecific variation of both the general protein composition and the different enzyme systems are studied. Possible changes in general proteins and enzymes during the development from larvae to adult were also investigated.

#4

USE OF *DROSOPHILA MELANOGASTER* PROBES IN THE STUDY OF THE MOLECULAR ORGANIZATION OF THE *APHIDIUS* GENOME. G. Gargiulo¹, F. Pennacchio², E. Tremblay³, C. Malva^{4*}. ¹Dipt. Genetica, Università di Napoli; ²Istituto di Entomologia, Università di Potenza; ³Dipt. di Entomologia, Università di Napoli; ⁴Ist. Internaz. Genetica e Biofisica, CNR, Napoli.

As a first approach to identify and characterize potential differences in the molecular organization of the genome of different species of *Aphidius*, total DNA of *A. ervi*, *A. microlophii*, *A. urticae* and *A. eadyi* was digested with HindIII/EcoRI, electrophoresed, blotted on nitrocellulose filters and probed with labelled total DNA from *A. ervi*. The existence of many differences encouraged us to carry out more detailed analyses, starting with the ribosomal RNA genes. By digesting the *Aphidius* DNA with several restriction enzymes and using the *Drosophila* 18S, 28S or full rDNA unit as probes, we have established the *A. ervi* rDNA restriction maps and demonstrated that rRNA genes can be useful probes to identify different species. However, our results show a very low level of intra-specific heterogeneity within the ribosomal repeating units as compared to *Drosophila*.

#5

CONSTITUTIVE HETEROCHROMATIN AND SPECIATION IN THE GENUS *PARASARCOPHAGA* (SARCOPHAGIDAE: DIPTERA). P. Gaur*, D. Kaul and U.R. Agrawal, Department of Zoology, University of Allahabad, Allahabad, India.

Metaphase chromosomes of ten species of flesh-flies of the genus *Parasarcophaga* have been studied cytologically by conventional staining, C-banding, N-banding and fluorochrome staining. All the species show a basic karyotype with 2n=12 (10A + XX ♀; XY ♂). The autosomes are remarkably similar in their gross morphology in these species but the sex chromosomes vary greatly in shape and size. C-banding reveals species specific differences in the amount and distribution of constitutive heterochromatin in the chromosomes. The totally C-band positive sex chromosomes show differential staining. Further characterization of the C-heterochromatin by N-banding and fluorochrome staining shows that the variations observed in the C-heterochromatin of the different species are not only quantitative but qualitative as well. The results reflect a possible role of C-heterochromatin in the evolution of karyotype leading to speciation in the genus *Parasarcophaga*. Details of the study will be discussed.

#6

CLONING AND CHARACTERIZATION OF AN ACTIN GENE FROM THE MEDFLY, *CERATITIS CAPITATA* (WEID.). D. Haymer*, J. Anleitner, S. Thanaphum, S. Saul and K. Houtchens, Dept. of Genetics and Dept. of Entomology, University of Hawaii, Honolulu, Hawaii, USA, 96822.

Actin genes have been cloned and characterized in many eukaryotes and they are well suited to studies of gene expression and evolution of multigene families. We have constructed a genomic library of the medfly, *Ceratitis capitata* in lambda Charon 4. Using the cloned *Drosophila melanogaster* actin gene as a probe, we have isolated and characterized a medfly actin gene from this library. Northern blot analysis indicates that this actin gene hybridizes to an abundant RNA transcript present in pupae and to a lesser extent to RNA transcripts present in embryo and adult stages. We also present evidence that the medfly genome contains at least two genes that exhibit extensive homology to the *D. melanogaster* 5C actin gene. We are completing the characterization of these actin genes in the medfly as well as in two other species that form the "trifly" species complex in Hawaii, namely *Dacus dorsalis* and *Dacus cucurbitae*.

Supported in part by USDA grants HAW00763-G and 87-CRSR-2-3072 managed by the PBAG.

#7

SEX ALLOCATION IN THE PARASITIC WASP DIGLYPHUS BEGINI (ASMEAD) (HYMENOPTERA: EULOPHIDAE). K.M. Heinz* and M.P. Parrella. Entomology Department, University of California, Riverside, CA USA 92521

D. begini is a common, external parasite of the serpentine leafminer, *Liriomyza trifolii* Burgess (Diptera: Agromyzidae). Since inundative releases of *D. begini* for leafminer control in greenhouse cut flowers and seed crops shows tremendous promise for commercial use, sex allocation in this wasp is important from an applied as well as evolutionary point of view. Field and laboratory evidence indicates that female progeny are derived from large leafminer larvae, male progeny from small larvae. Furthermore, the concept of larger and smaller have no absolute meaning, but appear to be a function of host size distribution. The overall sex ratio of the wasp is always male-biased. We are currently examining this phenomenon from a pathogenic and an adaptive point of view. Male-bias may arise due to microorganisms infecting the female reproductive system rendering them unable to produce female progeny. However, if selection favors traits which lead to a gain in fitness through the male versus female component, a male-bias could arise.

#8

INHERITANCE OF PHOTOPERIODIC RESPONSES CONTROLLING DIAPAUSE IN SPIDER MITES (ACARINA: TETRANYCHIDAE). S. Ignatowicz, Department of Applied Entomology, Agricultural University, Warsaw, Poland.

Photoperiodic reaction is a stable trait in the "Sambucus" (S) strain of *Tetranychus urticae* (Koch). However, the selection on non-diapause responded in a few generations. The two nondiapausing strains, ND₁ and ND₂, were selected from S and established in the laboratory. From crosses between the nondiapausing and S strains it appeared that "diapause" trait is semidominant over "non-diapause". The suppression of diapause in ND strains is dependent on the operation of single recessive $\underline{d}_1$ (in the ND₁-strain) or single recessive $\underline{d}_2$ and extrachromosomal determinant(s) (in the ND₂-strain). Recessives $\underline{d}_1$ and $\underline{d}_2$ concern one and the same allelomorph. Alleles $\underline{d}$ are stored in S (if not in all populations) at considerable frequency. The following genotype frequencies were found: DD=81%, Dd=18%, and dd=1%. Loci $\underline{a}$ -p and $\underline{d}$ are distinct. Inheritance of the length of the critical photoperiod seems to be polygenic in *T. urticae*. Crosses between individuals of two separate geographically populations produced hybrid and backcross progeny with an intermediate critical daylengths.

#9

TECHNIQUE TO PURIFY BIOTYPE 1 POPULATION OF BROWN PLANT-HOPPER, *NILAPARVATA LUGENS* (STÄL) (HOMOPTERA:DELPHACIDAE). Z. R. Khan*, International Centre of Insect Physiology and Ecology, P. O. Box 30772, Nairobi, Kenya, R. C. Saxena and A.A. Barrion, International Rice Research Institute, P. O. Box 933, Manila, Philippines.

A homogenous population of the brown planthopper, *Nilaparvata lugens* (Stål), was produced from single pairs of males and females which had been selected on the basis of their low food intake on rice varieties 'Mudgo' and 'ASD7' with *Bph1* and *bph2* resistance genes, respectively. The purity of such Biotype 1 population was further demonstrated for 3 generations based on differential nymphal growth and development, and adult longevity and fecundity on resistant 'Mudgo' and 'ASD7' and on the susceptible 'TN1' rice varieties.

#10

DNA CONTENT OF FEULGEN-STAINED SPERMATIDS AND EVOLUTIONARY IMPLICATIONS IN TENEBRIONIDS (COLEOPTERA). C. Juan and E. Petitpierre*, Lab. Genetica, Dep. Biologia, 07071 Palma de Mallorca (Spain).

Microdensitometric measures of Feulgen-stained spermatids have been made in eighteen species of Mediterranean tenebrionid beetles by using *Tribolium castaneum* as standard species, and then transforming the relative values into absolute ones. The spermatid DNA contents (pg) were: *Zophosis bicarenata* 0.23, *Tentyria grossa* 0.30, *T.schaumi* 0.26, *Pachychila subclunata* 0.28, *Hegeter brevicollis* 0.27, *Pimelia criba* 0.39, *Akis bacarozzo* 0.31, *Morica planata* 0.24, *Stenosis intricata* 0.18, *Asida planipennis* 0.29, *Elenophorus collaris* 0.29, *Scaurus striatus* 0.25, *Micrositus semicostatus* 0.28, *Ammobius rufus* 0.35, *Blaps lethifera* 0.86, *Tenebrio molitor* 0.52, *Misolampus goudoti* 0.36, and *Tribolium castaneum* 0.21. Although the range of genome sizes in tenebrionids is more than fourfold, most species have moderate differences, from 0.23 to 0.36 pg., which is in agreement with the noteworthy conservatism of diploid numbers and sex determining systems, since nearly 60% of the 156 known species share 9 + Xyp meioformula.

#11

KARYOTYPIC FORMULAE AND SUPERNUMERARY CHROMOSOMES IN EUROPEAN ALTICINAE (COLEOPTERA, CHRYSOMELIDAE). C. Segarra (1), E. Petitpierre (2). (1) Dpt. Genética. Fac. Biologia. Univ. Barcelona. 08028 Barcelona. Spain. (2) Dpt. Biologia. Fac. Ciències. Univ. Balears. 07071 Palma de Mallorca. Spain.

We have studied the karyotypic formula and sex determining system of six species of Alticinae belonging to three different genera: Altica, Psylliodes and Chaetocnema. The results are compared with those already known in other representatives of these genera. One of the species, *P. dulcamarae*, presents polymorphism for the chromosome number in the examined population. The polymorphism is due to the presence of 1 or 2 supernumerary chromosomes with a dot-like morphology. Intraspecific variability has also been found in two species of Aphthona, *A. venustula* and *A. depressa*. In the former it may be attributed to polymorphism while in the latter could not be confirmed the existence of intrapopulation variability. Another quite different case of supernumerary chromosomes was found in *A. herbigrada*. A population of this species showed some individuals with 13+Xy and others with two rod-like extra chromosomes that established contact in Metaphase I and segregated properly in Anaphase I. The extra bivalent was always located close to the sexual bivalent. The recorded cases of supernumerary chromosomes can be added to the few described ones in the family Chrysomelidae.

#12

THE OCCURRENCE OF TRIPLOID MALES AND THE SEX DETERMINATION MECHANISM IN A HAPLO-DIPLOID SAWFLY *ATHALIA ROSAE*.

T. Naito* and H. Suzuki, Entomological Laboratory, Faculty of Agriculture, Kobe University, Rokko, Kobe, 657 Japan.

We have succeeded in obtaining triploid males by sib-matings in the turnip sawfly *Athalia rosae*. The first discovery of triploid males in the Hymenoptera strengthens the multiple allele theory proposed for the sex determination mechanism by haplo-diploidy.

All the original females outcrossed to the males from different localities produced diploid females and haploid males. About a half of F₁ females mated with her brother produced diploid females and haploid males, and the rest half produced diploid males in addition to diploid females and haploid males. In the sib-matings within each of F₂ broods including diploid males, every female mated with her haploid brother produced diploid males, diploid females and haploid males, and other females crossed to her diploid brother produced triploid males, triploid females and haploid males in various proportions. The present results strongly suggest that the sex of *A. rosae* is controlled by multiple sex alleles on a single locus, where hemizygotes or homozygotes are male, while heterozygotes are female. Triploid males in this sawfly are supposed to have the same allele represented three times in this single locus, such as $X^aX^aX^a$.

#13

GENETIC AND MOLECULAR ANALYSIS OF A HOMEOTIC GENE CLUSTER IN THE RED FLOUR BEETLE. J.J. Stuart^{1*}, R.W. Beeman², R.E. Denell¹, T.K. Johnson¹. ¹Division of Biology, Kansas State University, Manhattan, KS 66506 and ²U.S. Grain Marketing Research Laboratory, ARS, USDA, Manhattan, KS 66502 USA.

A cluster of homeotic genes has been identified on the second linkage group of *Tribolium castaneum* (Beeman, Nature 1987). Genetic analysis indicated that this cluster (the homeotic complex or HOM-C) has many properties expected of the combined equivalent of the antennapedia (ANT-C) and bithorax (BX-C) complexes of *Drosophila melanogaster*. We have now identified 11 lethal complementation groups which have mutant phenotypes and map within the HOM-C. Reversion mutagenesis and gene dosage experiments have been used to distinguish between haplo-insufficient and gain-of-function dominant genotypes. Molecular analysis has involved identifying sequences homologous to Ant and Ubx DNA in the *Tribolium* genome, determining the extent of homology and identifying restriction fragment length polymorphisms.

#14

SEX-CHROMATIN IN THE CELL NUCLEI OF SEVERAL ORGANS OF THE SILKWORM MOTH, BOMBYX MORI (LEPIDOPTERA: BOMBYCIDAE). E. Sugai* and Q.Z. Pan, Faculty of Agriculture, Tokyo University of Agriculture and Technology, Fuchu, Tokyo 183, Japan.

The relationship between the sex-heterochromatin body (SB) and W chromosome (Sex-chromosome for female determination) was investigated with regard to several organs of the silkworm moth. The SB was clearly observed in the cell nuclei of the malpighian tubes, sucking stomach, rectal sac, oviduct and mucous glands of the female moth, while no SB was detected in those of the male moth. Of these organs, the sucking stomach was the most suitable for SB observation.

A single SB was observed per nucleus in the untreated diploid and the hot-water induced triploid moths, whereas two equal-sized SBs were detected in the tetraploid moth induced by cold-treatment. These results suggest that the SB in the cell nuclei of the moth corresponds to the W chromosome, and that the sex-chromosome structure in the somatic cells of the triploid and tetraploid female moths can be expressed as ZZW and ZZWW, respectively.

#15

GENIC ANALYSIS OF ECONOMIC TRAITS IN SOME STRAINS OF SILKWORM, BOMBYX MORI L. D.S. Tayade, Sericultural Research Unit, Marathwada Agricultural University, Parbhani 431 402, India.

The genic analysis in 4 x 4 diallel crosses of silkworm, Bombyx mori L. including reciprocals through components of variance method revealed that additive genetic variance played an important role in controlling most of the economic traits. The degree of dominance was found to be unity or greater than unity where dominance type of gene action was involved. High narrow sense heritability estimates were observed for percentage hatching, shell weight and filament length.

#16

EFFECT OF GENETIC DIVERSITY ON HYBRID PERFORMANCE OF SILKWORM, BOMBYX MORI L. D.S. Tayade, Sericultural Research Unit, Marathwada Agricultural University, Parbhani 431 402, India.

Six genetical populations viz: P1, P2, F1, F2, BC1 and BC2 derived from two multivoltine x bivoltine crosses (HM x NB7 & HM x NB18) were studied to determine the different gene effects, heterosis and inbreeding depression for economic characters of silkworm, Bombyx mori.

#17

ISOZYME VARIATION AND HISTORY OF SPREAD OF PEAR PSYLLA [CACOPSYLLA PYRICOLA (FOERSTER); HOMOPTERA: PSYLLIDAE] POPULATIONS IN FAR WESTERN NORTH AMERICA. T.R. Unruh, USDA-ARS, Yakima Agricultural Research Laboratory, Yakima, Washington, USA 98902.

Pear psylla populations show low levels of allozyme frequency differentiation among populations from southern California through southern British Columbia. This minimal population structure is consistent with this psyllid's purported high dispersal ability, its rapid spread through the region, and the recency of that expansion, i.e., some 200 generations, or 50 years, ago. An important exception to the homogeneity in allozyme frequencies lies in the 2 loci coding for general esterases; these genes show greater variation in frequency which may reflect different histories of selection through pesticide use patterns.

PARASITOIDS AS SELECTIVE FORCES IN THE ECOLOGY AND EVOLUTION OF INSECT HERBIVORES. P. Barbosa, Department of Entomology, University of Maryland, College Park, MD 20742, USA.

This presentation serves as an introduction to the symposium. What we have learned about the chemical ecology of host-parasitoid interactions has confirmed, in great detail, how closely attuned insect parasitoids are to their herbivore hosts. I suggest and illustrate that parasitoids have evolved the ability to find hosts and host-habitats using cues not easily altered by their herbivore hosts. That is, host and host-habitat finding by parasitoids often relies on cues associated with herbivore reproduction, mating and feeding. Therefore, it is difficult for herbivores to evolve counteradaptations without a significant reduction in fitness. Many parasitoids that evolved the use of certain cues are thus highly likely to act as strong selective forces on insect herbivores.

BEHAVIORS AND MORPHOLOGICAL STRUCTURES THAT DECREASE INSECT VULNERABILITY TO PARASITOIDS. P. Gross*, Department of Entomology, University of Maryland, College Park, Maryland USA 20742, and G. Rotheray, Royal Museum of Scotland, Chambers Street, Edinburgh, UK EH 1J.

Examples from the literature are cited to support the argument that insect behavior, morphology, and life history are important in determining vulnerability to parasitoids. Insects may avoid parasitoids by occupying safe microenvironments, by associating with ants, or by avoiding cues that are used as attractants by parasitoids. If found, insects may prevent successful parasitization by having tough cuticles or cocoons, or by employing any of a variety of behavioral defenses or escape tactics. The rate of success in biological control is greater when target species are sedentary.

PHYSIOLOGICAL FACTORS INFLUENCING PARASITOID-HOST RELATIONSHIPS. M. R. Strand, Department of Entomology, University of Wisconsin, Madison, Wisconsin 53706, USA.

The survival and successful development of endoparasitoids is influenced by the internal environment of the host. Host nutritional and endocrine factors often influence endoparasitoid development. However, the ability of the host's immune system to recognize and destroy the developing parasitoid is particularly important in determining host susceptibility to parasitism. The variation in host defensive and parasitoid escape mechanisms, and the evidence for coevolutionary interactions are examined.

INTERACTION OF HOST PLANTS AND EGG PARASITOIDS ON HERBIVORE LIFE HISTORIES AND SPECIATION. T.K. Wood, Department of Entomology & Applied Ecology, University of Delaware, Newark, Delaware, United States, 19711.

Speciation in the arboreal, univoltine *Enchenopa binotata* Say (Homoptera: Membracidae) complex was facilitated by shifts in host plant utilization. Host plant tracking results in *Enchenopa* life history phenologies that are asynchronous among the six host plant genera when they co-exist in the same microhabitat. A consequence of life history asynchrony is assortative mating leading to genetic divergence and reproductive isolation. Here I examine the influence of egg parasitoids (*Polynema enchenopa* Girault Hymenoptera: Mymaridae) in shaping *Enchenopa* life histories and promoting shifts in host plant utilization.

Polynema enchenopae emerges in the spring to attack *Enchenopa* eggs before they hatch. Wasp development in the spring is a function of temperature while the termination of *Enchenopa* egg dormancy is a function of host plant species. Emergence of wasps at the same time results in temporal windows of exposure that differ in magnitude leading to differential rates of parasitism for *Enchenopa* eggs on each host plant species. *Enchenopa* oviposition is prolonged on each host plant species over a two month period. The wasp has at least two generations during *Enchenopa* oviposition and imposes a high mortality on eggs deposited early in the season. Differences in oviposition phenology among the six host plant genera apparently results in differential effects of the parasitoids. In general, parasitoids appear to be selecting on some host plant species for delayed oviposition and increased female longevity. Host plant shifts in the univoltine *Enchenopa* complex may have resulted from the heavy mortality costs imposed by the multivoltine egg parasitoids.

GENETIC ASPECTS OF *DROSOPHILA*-PARASITOID INTERACTIONS. Y. Carton. Lab. Biol. Gen. Evol.. C.N.R.S., 91198 Gif, France.

A genetic basis for several aspects of the parasitization of *Drosophila* larvae by a hymenopteran parasitoid was investigated.

We show that genetic differences in host larval behaviour ("sitter" or shallow forager versus "rover" or deep forager) affect the frequency of parasitization by the wasp.

A genetic basis for encapsulation ability by host larvae was investigated with the isofemale line technique. The ability to encapsulate varies within a given natural population and is under partial genetic control. The average rate of encapsulation was the lowest for a host strain collected in the same site as the parasite strain. It seems that cellular reaction is less efficient within a population with which the parasitoid has interacted for a long period.

Investigations with the same technique were performed on parasitoid traits concerning success of parasitization. Comparisons of variances within and between isofemale lines of wasps and comparisons made between successive generations showed a genetic determinism for two traits: the overall developmental success and the ability to evade encapsulation.

PARASITOIDS AS SELECTIVE FORCES: LESSONS FROM BIOLOGICAL CONTROL. H. M. T. Hokkanen* and R. I. Vänninen, Agricultural Res. Ctr, SF-31600 Jokioinen, FINLAND.

Theoretical, empirical, as well as field and experimental evidence was used to study the effect of parasitoid and host evolution on the success of biological control. Two situations were considered: pre- and postintroductions evolution. The effect of preintroductions coevolution was studied by investigating 600 cases of control agent introductions involving evolutionarily new and old associations. New associations proved to have provided about twice as many successes as old associations in relation to attempts, suggesting that preintroductions coevolution, or the lack of it, may play a significant role in biological control.

Postintroductions evolution between the host and the parasite has been documented in extremely few cases, despite the over 200 successful cases of biological control, most of which have already persisted for decades. Our field and laboratory study of *Trichopoda pennipes* and its biocontrol host *Nezara viridula* shows that the host populations in the field have evolved at least 10% better reproductive success during the 150-200 years of interaction, compared with the initial situation. Simulation models of the host-parasitoid system indicate a potential for further still significantly increasing this resistance, should there be a pressure to do so.

PHYTOPHAGOUS PARASITES: HERBIVORY AS A SELECTIVE FORCE. Bernard D. Roitberg, Yves Carriere, Janice Cunningham and Robert Lalonde, Behavioural Ecology Research Group, Centre for Pest Management, Department of Biological Sciences, Simon Fraser University, Burnaby BC CANADA

We consider the kinds of damage (fitness costs) that herbivores direct upon their food plants. We begin our discussion, however, with a brief consideration of natural selection theory in order to classify the kinds of damage and the conditions under which such damage might lead to the evolution (i.e. changes in gene frequencies) of various plant characters. Following this, we consider the characteristics of three types of herbivores: (1) seed feeders, (2) fruit feeders and (3) foliage feeders. We then employ both conceptual and mathematical models to estimate damage levels and magnitude of selection. Finally, we make predictions on plant response to different selection regimes.

AGGREGATION BY PREDATORS AND PARASITOID: EFFECTS ON STABILITY AND PREY DENSITY. W.W. Murdoch, Department of Biological Sciences, University of California, Santa Barbara, California 93106, U.S.A.

The talk will describe two types of aggregation by parasitoids that have been examined in parasitoid-host models, and the sorts of field data needed to determine whether and when they occur in nature. Aggregation by parasitoids to patches containing more prey does occur in the field, but appears to be relatively uncommon. Such aggregation does occur in some predatory insects. The effects of aggregation upon host equilibrium density, and stability, in a discrete-time Nicholson-Bailey model are contrasted with the effects in a continuous-time model. Implications for biological control will be discussed. Other ways in which spatial heterogeneity can affect interactions between predator and prey, or parasitoid and host, will be mentioned.

AGGREGATION AND THE DYNAMICS OF APHID-LADYBIRD BEETLE INTERACTIONS: THE IMPORTANCE OF EXPLICITLY INCLUDING THE SPATIAL DIMENSION IN MODELS AND EXPERIMENTS. Peter Kareiva, Department of Zoology NJ-15, University of Washington, Seattle, Washington, U.S.A. 98195.

Numerous ecologists have noticed that the aggregation of predators can have profound consequences for the dynamics of arthropod predator-prey systems. However, most models and most field studies have neglected the mechanisms of aggregation while concentrating simply on its results. Our laboratory's work on ladybird beetle aggregation shows that the details of how a beetle moves through a heterogeneous environment are key to the role of aggregation in predator-prey dynamics. By altering the foraging behavior of ladybird beetles, habitat features such as plant architecture and plant patchiness determine whether or not prey escape the control of their coccinellid predators.

PARASITOID AGGREGATION AND SPATIAL DENSITY INDEPENDENCE OF PARASITISM: FIELD EVIDENCE FROM A SUCCESSFUL CASE OF CLASSICAL BIOLOGICAL CONTROL IN JAPAN. Y. Hirose*, T. Nakamura and M. Takagi, Institute of Biological Control, Faculty of Agriculture, Kyushu University, Fukuoka, 812 JAPAN.

Theoretical prediction that parasitoid aggregation in areas of high host density is necessary for effective biological control has been tested for few successful cases of classical biological control. We tested the prediction for the control of the red wax scale *Ceroplastes rubens* by its parasitoid *Anicetus beneficus*, which is one of the five successful cases of classical biological control in Japan, by combining direct field observations on parasitoid females with measurement of resulting patterns of parasitism in a citrus grove in Fukuoka. We found that the females aggregated in citrus trees of high host density, but that parasitism of hosts attacked by these females was density independent. Thus, the prediction is rejected in this successful case of control. We also examined the host-parasitoid interaction in the citrus grove over four years and found that the stability of the interaction comes from temporal density dependence of parasitism due to the intergeneration response of the parasitoid having two generations in a host generation.

HOST-PARASITOID POPULATION DYNAMICS IN A GREENHOUSE ECOSYSTEM. L.P.J.J. Noldus* and J.C. van Lenteren. Department of Entomology, Agricultural University, Wageningen, The Netherlands.

The topic of population dynamics of phytophages and aggregation by their natural enemies will be illustrated with results of studies on a greenhouse ecosystem. The system includes the host plant tomato, the greenhouse whitefly, *Trialeurodes vaporariorum* (Homoptera, Aleyrodidae), and its parasitoid *Encarsia formosa* (Hymenoptera, Aphelinidae). In a large greenhouse experiment, population dynamics and spatial distribution of host and parasitoid were monitored over several generations. A strong aggregation of immature as well as adult whiteflies was found at different levels of spatial distribution. Subsequently, various small-scale experiments have been conducted on whitefly behaviour, as the basis for the observed distributions, as well as on the foraging behaviour of *E. formosa*, as far as relevant to possible aggregation at the population level. The results of these experiments will be discussed in the context of current theories on the role of aggregation by natural enemies in the population dynamics of their hosts.

AGGREGATED AND RANDOM OVIPOSITION BY *CYZENIS ALBICANS*: EFFECT ON WINTER MOTH POPULATIONS IN BRITISH COLUMBIA, CANADA. Jens Roland, Agriculture Canada Research Station, 6660 N.W. Marine Drive, Vancouver, Canada, V6T 1X2.

Cyzenis albicans (Tachinidae), introduced to control winter moth in British Columbia, exhibit strong aggregation of oviposition in response to increased levels of host-caused leaf damage on oak trees. On apple trees *Cyzenis* readily oviposits, but do so randomly with respect leaf damage or host density. This difference in spatial pattern of oviposition on the two tree species increases as mean density of winter moth declines. If aggregated attack by *Cyzenis* is important in stabilizing host populations, we would predict greater stability (defined as the standard deviation of log-transformed densities) in oak woods than in the apple orchard. Also, we should see increased stability in the oak wood after parasitoid introduction. Winter moth populations have in fact been more stable in the apple orchard than in the oak wood. In both habitats, densities among sub-populations have gone through a period of reduced stability since parasitoid introduction.

GENERALIST PREDATORS AND PREY SPECIES DIVERSITY. I. Hanski, Department of Zoology, University of Helsinki, P. Rautatiekatu 13, SF-00100 Helsinki, Finland.

Generalist predators may decrease, increase or have no effect at all on species diversity in their prey assemblage depending upon a great number of factors. After outlining a range of possibilities, the paper will focus on the situations in which the prey species have more or less independently aggregated spatial distributions. In this case, which is common for prey species with similar ecologies, spatially density-dependent predation becomes frequency-dependent, and tends to facilitate coexistence. Inversely density-dependent predation would do the opposite. Models and examples are discussed.

UNDERSTANDING THE EVOLUTION OF INSECT LIFE CYCLES; THE ROLE OF GENETICAL ANALYSIS. D.A. Roff, Department of Biology, McGill University, Montreal, Quebec, Canada H3A 1B1.

A central question of evolutionary biology is "What maintains phenotypic variation?". In this paper, I examine the solutions suggested by models based on the assumption that fitness is maximized (optimality models), and models based upon genetic architecture (genetic models). It is shown that the solutions may be very different, and hence optimality models must be supplemented by a genetic analysis. In the absence of any genetic component, phenotypic variation can be maintained by an appropriate norm of reaction. The important question is therefore "To what extent is phenotypic variation in life cycle events a consequence of appropriate norms of reaction and to what extent is it due to variation in mean genotype?". The heritability of life cycle traits is significant and, in part at least, underlies the phenotypic variation. Factors maintaining additive genetic variation are environmental heterogeneity, GxE interactions and variable pleiotropy. The potential importance of these three mechanisms is explored.

PATTERNS OF PLEIOTROPY IN INSECT LIFE HISTORIES. M. Rose (USA)

No Abstract

GENOTYPE-ENVIRONMENT INTERACTION AND NATURAL SELECTION IN A POLYPHAGOUS HERBIVORE: EXPERIMENTAL ESTIMATES OF THE POTENTIAL FOR EVOLUTION. S. Via, Dept. of Entomology and Section of Ecology & Systematics, Cornell University, Ithaca, NY USA 14853.

How do polyphagous insects adapt to a range of hosts that may each impose a different selective regime? The process of evolution in this situation depends upon (1) patterns of genetic variability in insect populations (both within and between hosts) for characters associated with host plant use and (2) the strength of natural selection that the plants exert on insect populations. We have experimentally estimated both of these components of evolution in the pea aphid (*Acyrtosiphon pisum*) using a reciprocal transplant of clones between two crop species. By making life tables for individual clonal replicates on each of the two crops under field conditions, we estimated the relative fitness of each clone in each of the environments. The theory and practice of using demographic measures on individuals to estimate fitness will be discussed. The potential for evolution is directly related to the variance in fitness within each environment and the clonal covariance in fitness across the hosts. Results suggest that adaptive divergence of populations on the two crops has already occurred, and that further evolution of adaptedness to alfalfa and clover is still to come.

PHENOTYPIC PLASTICITY OF PHENOLOGICAL TRAITS: GENETIC BASIS, EVOLUTIONARY CHANGE, AND ADAPTIVE SIGNIFICANCE. K.P. Sauer, Department of Evolutionary Biology, University of Bielefeld, 4800 Bielefeld, FRG.

One of the major problems in evolutionary ecology is to what extent selection can produce a response in any trait depending on environmental constraints. This paper is concerned with the aestival and hibernal dormancy in *Mamestra brassicae* and the hibernal diapause in *Panorpa vulgaris*. A highly specific recognition system, capable of "foreseeing" and distinguishing between two critical points in time (onset of drought and frost) exists in *M. brassicae*. The onset of aestival and hibernal dormancy is triggered by day lengths exceeding two innate thresholds. Furthermore, the innate thresholds are characterized by a temperature dependent norm of reaction. The adaptive significance of both the variation in day length thresholds and temperature dependence is discussed with respect to the synchronization of life cycles with the seasonal changing environmental conditions. The special case of *P. vulgaris* is discussed as second example.

GENETIC STRUCTURE AND ADAPTIVE OPPORTUNITIES. S.M. Scott and H. Dingle*, Department of Entomology, University of California, Davis, California, USA 95616.

Insect life histories consist of traits which may interact or vary independently of each other. Traits influenced by the same genes are correlated and this correlation forces variation in one trait to follow variation in any correlated traits. In this way genetic structure may constrain adaptive opportunities. In the absence of genetic correlations, traits are free to vary independently and to evolve towards individual optima. Reproductive timing may be an example in insects.

Life history flexibility and resultant adaptive opportunities may be achieved in several ways even when traits are genetically correlated, including plastic responses to environmental stimuli, maternal effects which integrate responses to environment over at least two generations (thus controlling future behavior), and behavioral traits such as migration and diapause. In addition, populations may contain genetic variance for phenotypic plasticity as manifested by genotype x environment interactions. We shall use data from studies on milkweed bugs, grasshoppers, and other insects to explore questions concerning life history flexibility and how this relates to patterns of genetic structure, maternal effects and other factors.

EVOLUTION OF INSECT LIFE HISTORIES IN TEMPORALLY VARIABLE ENVIRONMENTS. Fritz Taylor, Department of Biology, University of New Mexico, Albuquerque, NM, 87131, USA.

Two observations characterize much of selection in nature. First, an intermediate, or optimal, phenotype is often favored and, second, this optimal phenotype varies between generations. Evolutionary theory has dealt with the problems that these facts pose for developing predictions about phenotypic evolution by assuming that selection over the long run maximizes geometric mean fitness.

This study tests this assumption using standard models from quantitative genetics. The goal is to derive some general results for when use of the geometric mean is and is not appropriate for making predictions about short-term evolution, i.e. the range of time over which predictions can generally be tested. To this end, I vary heritability, temporal variation and autocorrelation of the optimal phenotype, and symmetry of the fitness function. The geometric mean does predict long-term behavior under almost all conditions. The results clarify what quantities need to be measured to test predictions about short-term behavior of the mean phenotype experiencing temporally varying, optimizing selection.

OPPORTUNISTIC DIAPAUSE: A LINK BETWEEN TROPICAL AND TEMPERATE LIFE CYCLES IN GROUND CRICKETS. Sinzo Masaki, Laboratory of Entomology, Faculty of Agriculture, Hirosaki University, Hirosaki 036, Japan.

Diapause increases fitness by enabling insects to escape from seasonal risks, while it decreases fitness by delaying reproduction where there are resources available throughout the year as in moist parts of the tropics. In Southeast Asia, in fact, ground crickets such as *Dianemobius fascipes* and *D. taprobanensis* have no diapause and any other seasonal regulatory mechanism in their life cycles. By contrast, a stabilized egg diapause is a predominant means of overwintering in the closely related species inhabiting the temperate parts of the Japanese Islands. In the subtropical region where the winter weather fluctuates between the optimal and suboptimal levels, the direction of selection pressure may not be consistent, and the fitnesses with and without diapause are in a state of dynamic balance. Under such circumstances a polymorphic life cycle might be expected to evolve. There is, however, another novel type of intermediate adaptation by an "opportunistic" diapause that is highly sensitive to direct effects of temperature. This might be an evolutionary link between the tropical and temperate adaptations.

EVOLUTION OF INSECT PHENOLOGY AND DEMOGRAPHY. W. E. Bradshaw* and C. M. Holzapfel, Department of Biology, University of Oregon, Eugene, OR 97403, USA.

Life history traits of insects vary among geographic populations and this variation is generally taken to imply genetic differentiation of populations. Among populations of the pitcher-plant mosquito, *Wyeomyia smithii*, those traits that exhibit the greatest phenotypic change along geographic gradients also exhibit the highest population heritabilities. The greatest change along geographic gradients occurs among traits involved with seasonality (phenology) rather than those involved with behavior, development time, survivorship, and fecundity (demographics). However, even traits that show no significant change along geographic gradients may still show significant local differentiation that can be attributed to selection, drift, or both.

The two major implications are first, that phenological and demographic traits may evolve independently and, second, that, even within a single species, geographic variation may be due to drift, selection, or both, depending upon the specific trait involved.

EVOLUTION OF MUTUALISTIC LIFE CYCLES IN YUCCA MOTHS AND FIG WASPS. F. Kjellberg, J. Bronstein*, and J. Addicott, CEPE, Centre National de la Recherche Scientifique, Montpellier, France F-34033, and Department of Zoology, University of Alberta, Edmonton, Alberta, Canada T6G 2E9.

Yuccas (*Yucca* spp.) and figs (*Ficus* spp.) both depend on obligate species-specific pollinators (*Tegeticula* moths and agaonid wasps, respectively) whose offspring are obligate seed predators. We compare processes and consequences of plant-insect coevolution between these two systems. Both insects should be under strong selection for increasingly effective seed predation; both have close relatives ("cheaters") that are strict seed predators on the same plant. Abortion of developing fruits (which contain seeds and seed-feeding larvae) is one means by which the plant could respond to overexploitation. Our data indicate that fruit abortion is common in yuccas but absent or very rare in figs. We suggest two major causes of this difference. (1) Fruit abortion would constitute an immediate cost in male reproductive success for figs: when mature, the pollinators' female offspring collect and depart with pollen from their natal plant. This is unlikely to be true for yuccas. (2) Fruit abortion should be especially costly when fruit set is pollen-limited. Pollen-limited fruit set is more common in figs than in yuccas: extreme protogyny has resulted in year-round flowering in fig populations, with very few potential mates and consequently high probabilities of reproductive failure each time an individual flowers. We also compare and discuss causes of the strikingly different patterns of plant-pollinator cospeciation in these two systems.

THE EVOLUTION OF SIZE AND ITS IMPACT ON LIFE-HISTORIES Francis Gilbert, Department of Zoology, Nottingham University, Nottingham NG7 2RD.

Size is a major determinant of life-history strategy and perhaps is the primary axis of variation for most life history components. Analysing the effects of size is confounded by the influence of phylogenetic constraints. For one group of insects, the hoverflies or flower-flies (Diptera, Syrphidae), the evolution of size and life-historical components are considered in the light of their phylogeny.

INSECT HERBIVORES, HERBIVORY AND PLANT SUCCESSION. V.K. Brown, Imperial College (University of London) at Silwood Park, Ascot, Berks SL5 7PY, U.K.

The community structure and organisation of plants and their associated insect herbivores varies during secondary succession. Both the numerical abundance and guild structure of insects are related to plant species composition and structure. Furthermore, a number of insect life-cycle traits change during succession.

Results from a comparative study in a New World site (Iowa, U.S.A.) and Old World site (southern Britain) illustrate differences in the relative importance of insect guilds, in particular two major herbivorous groups (sap-feeders and chewers). Using manipulative field experiments, the impact of these herbivorous groups on the establishment and development of their host plant communities is discussed.

INSECT LIFE CYCLES IN PATCHY EPHEMERAL HABITATS: IMPLICATIONS FOR SELECTION AND COMPETITION. B. Shorrocks (UK)

No Abstract

COEVOLUTION OF PLANTS AND INSECT HERBIVORES: TEMPO AND ORCHESTRATION. M.R. Berenbaum, Department of Entomology, University of Illinois at Urbana-Champaign, Urbana, IL 61801-3795 USA.

The "arms race" view of coevolution between plants and herbivorous insects has been subject to scrutiny in recent years. The likelihood of coordinated reciprocal genetic changes between organisms differing in generation time, population structure, and selective impact is difficult to evaluate a priori, and assessments of congruence between host and insect phylogenies are necessarily a posteriori. The "reciprocal radiation" model accounts for a nonrandom fit to association by descent, with certain deviations from fit attributable to phytochemical divergence with taxa. Host transfer due to geographical proximity, ecological similarity, or chemical convergence in contrast should generate patterns distinct from those produced by mutual descent. The lepidopteran family Oecophoridae (sensu lato) is examined with respect to patterns of phylogenesis in herbivores and hostplants. Relationships at the species, genus and subfamily level are evaluated in the context of host phylogeny, ecology, geography, and chemistry.

MIGRATION AND THE COORDINATION OF LIFE CYCLES. C. Solbreck (Sweden)

No Abstract

LIFE CYCLE STRATEGIES AND THE HABITAT TEMPLET. P.J.M.. Greenslade, CSIRO Division of Soils, Private Bag 1, Glen Osmond, South Australia 5064, Australia.

An insect's habitat can be defined by abiotic factors: predictability or durational stability and relative favorableness. These are the two axes of the habitat templet with its third, diagonal axis: biotic unpredictability or intensity of biotic interaction. A habitat's position on the templet predicts the strategies or combination of life history and other traits that will be favored by selection. Recently, T.R.E. Southwood has emphasised the identity of this concept as formulated independently by a number of authors, among them R. Sibly and P. Calow, who considered total investment in reproduction and the trade-off between size and number of offspring. These attributes have been much discussed in relation to the predictability or r-K axis of the templet. Here, with additional features (capacity for dormancy, dispersal and simplification life histories), they are examined in relation to the stress axis.

OVERVIEW OF FILTER-FEEDING IN AQUATIC INSECTS. R.S. Wotton, Department of Life Sciences, University of London, Goldsmiths' College, Rachel McMillan Building, Creek Road, London SE8 3BU, United Kingdom.

Filter-feeding aquatic insects use a wide array of mechanisms to extract food from the water column. The food will consist of particulate and dissolved organic matter, both living and dead, and the relative amounts of each in the diet will vary with the type of feeding mechanism employed, and the location of the animal within a habitat. Studies which investigate the nutritional importance of the whole diet of filter-feeding aquatic insects are very difficult to undertake but are necessary if we are to understand their role within the ecosystem.

HYDRODYNAMICS OF FILTER-FEEDING INSECTS.

D. A. Craig, Department of Entomology, University of Alberta, Edmonton, Alberta, CANADA T6G 2E3.

Using black fly and caddisfly larvae as examples, flow regimes in their habitats will be related to interactions between individuals and their filtering mode of feeding.

Flow around a black fly larva and through its labral fans will be dealt with in detail and the fundamental principles of flow involved will then be used to examine other filter feeders.

Theoretical studies on filtration will be considered in relation to those involving size of particles captured by black fly larvae. Does structure and size of filter influence what is captured?

Further advancement of our understanding of filter feeding will require studies using scaled-up models of filtration structures and investigations into mucosubstances used by some filter feeders and the processes involved in the actual approach and adhesion of particles to the filtration structures.

ROLE OF MICROBES IN FILTER-FEEDING INSECTS. D.L. Lawson and M.J. Klug, Kellogg Biological Station, Michigan State University, E. Lansing, MI 48824.

In natural habitats microorganisms may constitute a significant component of the potential dietary substrates available to filter-feeding insects, yet the role of microorganisms in the feeding ecology of these insects remains poorly recognized. Reasons for this lack of work stems from methodological considerations, as adequate population estimation and controlled feeding and assimilation studies are time consuming and often beyond the scope of traditional laboratories. For the quantification of the microbial contribution to filter-feeding insects, one or more of the following must be considered: 1) determination of microbial densities in the habitat; 2) demonstration of mechanisms for the efficient capture and/or ingestion of microbial cells; and 3) demonstration of larval assimilation and/or growth on microbial biomass at field densities. We will discuss the above in relation to what is known of the feeding ecology of filter-feeding insects and from our studies of the mosquito *Aedes triseriatus*. In particular, we have conducted studies utilizing a ^{15}N labeling technique which directly quantifies the contribution of microbial N to filter-feeder growth. These studies in combination with habitat analysis and microcosm experiments provide further understanding of the role of microorganisms in the nutritional ecology of filter-feeding insects.

FUNCTIONAL FEEDING MORPHOLOGY IN MOSQUITO LARVAE (CULICIDAE) C. Dahl, Dept. of Zoology, Section of Entomology, Uppsala University, Box 561, S-751 22 Uppsala, Sweden

Feeding structures in the larval head capsule are the most variable subsystem of the alimentary canal morphology. This subsystem is directly related to suspension feeding or brushing behaviour. All culicid species have to combine feeding activity and air intake from the water surface. Several functional solutions exist which combine or segregate these conflicting activities. The multidimensional interdependence between morphological variations, feeding categories, behaviour, habitat segregation, particle sizes and the physico-chemical conditions in stagnant water, necessitate reevaluation of or further studies in vital areas, descriptive or process related. Some of these are: the degree of facultative behaviour in species or individuals in relation to mouthpart variations, mechanistic processes for economization of feeding movements, coordination of spatial and temporal processing of particle uptake, relation of particle size to selection in feeding categories, and different principles for particle flow entrainment and origin. Principles for particle concentration should be related to recent research on laminar flow and thin boundary layers for understanding the role of filaments and setae in feeding. Studies of direction of evolutionary changes in head architecture need phylogenetic comparisons.

NATURAL FOOD AND FEEDING BEHAVIOR OF MOSQUITO LARVAE. E.D. Walker and R.W. Merritt, Department of Entomology, Michigan State University, East Lansing, MI 48824.

We have been studying the natural food and feeding behavior of *Aedes triseriatus* and *Anopheles quadrimaculatus* larvae using: (1) gut analysis, (2) examination and experimental manipulation of food resources in larval habitats, (3) direct behavioral observations of larvae, and (4) high-speed microcinematography of mouthparts. A quantitative method employing DAPI stain and epifluorescence microscopy was developed for gut analysis of mosquito larvae. Food items of four different classes (bacteria, organic detritus, protozoa, and algae) can be differentiated by fluorescence properties, color, and shape. *Aedes triseriatus* guts contained few protozoa and no algae, while *Anopheles quadrimaculatus* guts contained protozoa, algae, and diatoms.

An experiment showed that tree holes with *Aedes* larvae had fewer bacteria than did tree holes without larvae, suggesting that the larvae graze the bacteria, and it may provide an important food source.

Examination of water samples taken from a marsh habitat containing *Anopheles* larvae showed that the surface microlayer (from which *Anopheles* larvae feed) had higher numbers of bacteria than did subsurface waters. High-speed microcinematography of *Anopheles* feeding showed that larvae produce a "plume" of particles which passes downward into the water column and may serve an important function in food acquisition.

NUTRITIONAL ASPECTS OF FILTER-FEEDING AND DRINKING IN MOSQUITO LARVAE. R.H. Dadd, Entomology Department, University of California, Berkeley, CA 94720, USA.

Early studies of filter feeding suggested that little water was ingested. Yet growth in synthetic media with all nutrients in solution must depend on drinking, and osmoregulation involving copious drinking has now been quantitated for several salinophile species. A recent study of freshwater species showed that various exogenous factors, among them dilute colloids in solution, could increase the drinking rate. Observation of filtering activity showed that mouthbrush movements were impeded in dilute colloid solutions for all species examined. If drinking is locked in to overall filter-feeding activity, drinking would be retarded in dilute colloid solutions, as it probably is for *Anopheles albimanus*. In contrast, drinking rates of *Aedes* and *Culex* species doubled in the colloid solutions, and this indicates that drinking can be decoupled from filtering and the drinking rate increased. In natural waters, microhabitats with significant concentrations of organic colloids would most likely be present at the interface with bottom muds and detritus; browsing at such locations, even though filtering were impeded, might be nutritionally advantageous if drinking were enhanced.

BEHAVIOR AND FILTER FEEDING BIOLOGY OF EUROPEAN HYDROPSYCHID CADDISFLIES. Lena B.-M. Petersen, Stream and Benthic Ecology Group, Department of Ecology/Limnology, Box 65, 221 00 Lund, Sweden.

The importance of food and habitat selection as factors affecting the distribution of hydropsychid caddisflies has been discussed in running water ecology. A clear understanding of larval behavior is the key to this issue. In my experiments, food preference was determined in a series of choice experiments and direct observations on food handling. The larvae were highly selective in food choice with similar food preferences for the three species tested. Food choice varied with the degree of hunger, with a satiated animal more selective than a starved. At the same location differences between species in gut content was explained by microhabitat and net structure and not by particle selectivity. The structure of hydropsychid species guilds over a geographic area was explained by the quantity of high quality food, and by species differences in aggressive behavior and sensitivity to environmental stress. In Swedish hydropsychids, certain alpha species, dominate the guild. In one-on-one contests over net spinning sites, alpha species were more aggressive than coexisting beta species of the same instar and mass. The intensity of the aggressive encounter was related to both the degree of satiation of the individual and the presence of a food particle. Under most circumstances beta species tended to lose. However, in laboratory experiments and from field observations beta species were more tolerant to environmental stress.

CURRENT STATUS OF KNOWLEDGE ON FILTER-FEEDING TRICHOPTERA.

J.B. Wallace, Department of Entomology, University of Georgia, Athens, Georgia, 30602 U.S.A.

Net-spinning caddis larvae have evolved a striking array of structures and silken capture nets which are deployed in streams to remove particles from suspension. Feeding habits of the various species range from primarily predaceous to ingestion of microfine particles, < 10 microns in diameter. Anatomical structures used in feeding and catchnet architecture are coadapted under mutual constraints imposed by the mechanics of filtering and handling particles of different sizes. The various driving variables suggested to account for diversification of catchnet structures will be discussed. The mechanics of filtration, including volume filtered, drag coefficients, particle size distributions and relative capture efficiencies, and the relative importance of sieving and non-sieving mechanisms remain largely unknown for nets of different pore size and structure. However, research into the mechanics of filtration should not ignore behavioral aspects of feeding by the organisms.

A PHYTOCENTRIC PERSPECTIVE OF PHYTOCHEMICAL INDUCTION BY HERBIVORES. C.G. Jones*, J.S. Coleman, Institute of Ecosystem Studies, Millbrook, NY 12545, USA, and Department of Biological Sciences, Stanford University, Stanford, CA 94305, USA.

Little attention has been given to the biological characteristics of plants in the design and interpretation of induction studies. We show how understanding the effects of plant genotype, phenology, ontogeny and interaction with the abiotic and biotic environments can help predict: the species and age of plants that are most likely to be phytochemically inducible; the environmental conditions most likely to promote or inhibit induced responses; and the feeding habits of specific herbivores that make them likely or unlikely to be affected by phytochemical changes.

RESPONSE MECHANISMS OF PLANT TISSUES TO HERBIVORE FEEDING. C.A. Ryan, Institute of Biological Chemistry, Washington State University, Pullman WA 99164.

The induction of antinutrient proteinase inhibitor proteins in plant leaves in response to herbivore feeding or other severe mechanical damage has provided a system to study the biochemistry and molecular biology of the process and its relationship to natural plant defense. Fragments of the plant cell walls, produced by herbivore feeding, appear to be a part of the signalling process. Cell wall-derived galacturonic acid dimers and trimers, when supplied to excised tomato, potato or alfalfa plants, induce the expression of proteinase inhibitor genes in leaves. The role of these oligomers and of other possible signals in the recognition-communication system is being investigated. Proteinase inhibitor genes from potato and tomato have been isolated and characterized to further study the mechanism of wound induction. Experiments have begun to introduce the proteinase inhibitor genes into crop plants and to assess the usefulness of the genes to strengthen natural defensive responses. (Supported in part by NSF grants DCB-8315427 and DCB-839344.)

ALKALOID INDUCTION IN WILD TOBACCO (*NICOTIANA SYLVESTRIS*) Ian T. Baldwin, Section of Neurobiology and Behavior, Cornell University, Ithaca, New York U.S.A 14853.

Wild greenhouse-grown tobacco undergo significant increases in the alkaloid contents of their undamaged leaves when subjected to real (2.2x), simulated (4.x) and pseudosimulated (5.5x)--mimicing only the amount and timing of damage-- herbivory from the larvae of *Manduca sexta* compared to control, undamaged plants. This induced response can reach a maximum 9 days after the end of leaf damage and is due to a 10-fold increase in the alkaloid concentration of the xylem stream entering the leaf. The response can be inhibited by growing plants in pots or applying auxins to the damaged leaf edges. These two techniques were used to examine the effects on herbivore growth and the costs to the plants of this induced defense.

EFFECTS OF PLANT CARBON/NUTRIENT BALANCE UPON LONG-TERM INDUCED DEFENSE IN WOODY PLANTS. J.P. Bryant*, K. Danell and F. Provenza. Institute of Arctic Biology, University of Alaska, Fairbanks, Alaska 99775-0180 USA.

Severe herbivory can alter the nutritional quality of leaves for insect herbivores in subsequent years. In some cases nutritional quality declines whereas in others it increases. These opposite responses of woody plants to herbivory depend upon the plant's inherent growth rate (slow vs. fast) and the type of herbivory (severe early growing season defoliation vs. pruning). We propose that this variation in response can be explained as a consequence of herbivory induced variation in plant carbon/nutrient balance. We present a formal model of this hypothesis and evidence in support of it from several ecosystems. We conclude that so called "long-term inducible" defenses are passive responses to herbivory rather than active evolved defenses targeted specifically at insect herbivores.

CARBON ALLOCATION, PHENOTYPIC PLASTICITY AND INDUCED DEFENCES. J. Tuomi*(1), P. Niemelä (2) and T. Fagerström (1), (1) Dept of Ecology, Univ of Lund, S-223 62 Lund, Sweden, (2) Dept of Biology, Univ of Turku, SF-20500 Turku, Finland

Carbon-based secondary compounds may have evolved as plant metabolites that have later acquired additional functions, such as defence against herbivores and pathogens. This is consistent with hypotheses predicting an accumulation of carbon-based allelochemicals under conditions (e.g. nitrogen deficiency) tending to suppress protein synthesis and plant growth. This also implies an induced accumulation of carbon-based allelochemicals under conditions where leaf removal reduces more plant mineral nutrient than carbon pools. Such responses should be relatively localized within plants insofar as plant parts are semi-autonomous units responding separately to external stresses. In contrast, active defence responses may be triggered by chemical cues transmitted from attacked to non-attacked plant parts. Thus active defences may be related with enzymatic regulation, whereas responses to varying resource pools may be mediated by substrate availability.

SQUASH BEETLES, CUCUMBER BEETLES, AND INDUCIBLE CUCURBIT RESPONSES. D.W. Tallamy* & E.S. McCloud, Department of Entomology and Applied Ecology, University of Delaware, Newark, DE, 19717-1303, USA.

Plants in the genus *Cucurbita* are noxious to most herbivores, presumably because of the extreme bitterness of triterpene cucurbitacins. It has been assumed that the inducible properties of cucurbitacins in response to foliar tissue damage are adaptive responses against non-adapted herbivores. Though physiologically non-adapted, a few herbivores, such as *Epilachna* squash beetles, utilize the dynamics of the induced response to avoid cucurbitacins. Physiologically adapted herbivores, such as *Diabrotica* cucumber beetles, challenge cucurbit defenses in a different way: cucurbitacins are phagostimulants for these insects and increase rather than decrease the attractiveness of cucurbit tissues. The interaction between cucurbit inducible responses and these two herbivore guilds will be discussed in detail.

RESPONSES OF LEAF BEETLES TO DAMAGE INDUCED CHANGES IN THEIR SALICACEOUS HOSTS. M.J. Raupp* and C.S. Sadof, Department of Entomology, University of Maryland, College Park, Maryland 20742, USA.

Several recent studies have revealed major phytochemical changes in plants following disturbance by a variety of biotic and abiotic agents. Our studies focus on the behavioural and physiological responses of the leaf beetle *Plagioderia versicolora* (Coleoptera: Chrysomelidae) to changes in the quality of willow leaves that have been damaged. Larvae that eat damaged leaves suffer greater mortality, slower development, and reduced growth compared to those fed undamaged leaves. Adult beetles produce fewer eggs when fed damaged leaves and actively avoid damaged leaves under laboratory and field conditions. Previous damage reduces subsequent herbivory on willow shoots in the field. These responses help explain patterns of host utilization in *P. versicolora*.

A DETAILED CHEMICAL MODEL FOR SHORT-TERM DEFENSIVE INDUCTION IN QUAKING ASPEN. T.P. Clausen*, J.P. Bryant, P.B. Reichardt and R.A. Werner, Department of Chemistry, University of Alaska, Fairbanks, Alaska 99775-0520 USA.

Quaking Aspen (*Populus tremuloides*) foliage undergoes a sequence of chemical changes following a simulated herbivory. Initially, levels of two glycosides (tremulacin and salicortin) rise within 24 hours of damage. Leaf crushing, as occurs during leaf chewing, results in the enzymatic conversion of these glycosides into two new glycosides (salicin and tremuloiden) and 6-hydroxycyclohexenone. This latter compound can be converted into phenol or catechol (both toxic substances) or captured by nucleophiles depending upon gut conditions. Bioassays using the large aspen tortrix (*Choristenuera conflictana*) confirm the defensive nature of these changes. These results provide the first detailed model of a short-term induced chemical defense against herbivores in woody plants.

INDUCED DEFENSIVE REACTIONS IN CONIFER - BARK BEETLE SYSTEMS. K.F. RAFFA, Department of Entomology, University of Wisconsin, Madison, WI, USA 53706.

Conifers respond to invasion by bark beetles & their microbial symbionts by forming necrotic lesions & secreting resin at the attack site. The chemical composition of reaction tissue in both quantitatively & qualitatively different from constitutive tissue. Compounds that accumulate during defensive responses are insecticidal, repellent, & fungistatic.

Induced responses to bark beetle/microbial complexes, unlike reactions to defoliators, are localized, & lethal to the invading agents. Reproduction by primary bark beetles is contingent on killing the tree, and conversely host failure in resisting attack is fatal. Thus there are intense selective pressures on both host & parasite with regard to the mobilization of & interference with induced defenses, respectively.

Trees respond to attack by accumulating disproportionately high concentrations of compounds that most disfavor beetles & associated fungi. Beetles can exhaust a potentially effective host response through mass attack, but extremely high rates of resin flow can interfere with this adaptation. Consequently, the outcome for each tree is determined by competing reaction rates of defensive chemicals & beetle arrival.

THE EFFECTS OF RAPID AND DELAYED INDUCED RESISTANCE IN BIRCH. E. Haukioja, Laboratory of Ecological Zoology, Department of Biology, University of Turku, SF-20500 Turku 50, Finland.

Induced resistance in birch foliage against insects is triggered by insect feeding and mechanical damage. The rapid form of resistance affects the insect generation which triggered the response and thus dampens fluctuations in density. The delayed form of induced resistance, affecting the next generation(s) of insects, has an opposite effect. In the white birch (*Betula pubescens*) these two forms of inducible resistance presumably are separate phenomena because their relative importance varies among birch provenances. The delayed induced resistance may last for 2 - 4 years and reduces performance of lepidopteran and hymenopteran species. The delayed resistance in birch provenances from and outside the outbreak range of the autumnal moth *Epirrita autumnata* reduced the reproductive capacity of female (by 70 % or more) and male moths. Foliar damage induced no delayed effect on *Epirrita autumnata* in two birch provenances from the non-outbreak area.

THE EFFECTS OF INDUCIBLE RESISTANCE IN BIRCH FOLIAGE ON DIFFERENT ASPECTS OF THE PERFORMANCE OF HERBIVOROUS INSECTS. S. Neuvonen, Department of Biology, University of Turku, Turku 50, SF-20500 Finland.

The damage induced changes in birch foliage may affect the behaviour, nutritional ecology, mortality and/or fecundity of herbivores. The effects of rapid inducible resistance are strongest in early season foliage and have been shown with various insect species as longer larval periods and lower survival. The effects of delayed inducible resistance are best known with the geometrid *Epirrita autumnata* (Bkh.) which periodically defoliates mountain birch forests in northern Fennoscandia. The consumption rates of larvae are much lower on trees defoliated in the previous year than on control trees. Also the food utilization efficiency is reduced. Consequently, the growth rates and final weights (which correlate with fecundity) of *E. autumnata* are strongly reduced in the year following damage. Also larval mortality is higher on previously defoliated trees.

DOES THE NEOTROPICAL LIANA, *OMPHALEA DIANDRA* INDUCE THE DIURNAL MOTH *URANIA* TO MIGRATE? Neal G. Smith, Smithsonian Tropical Research Institute, Apartado 2072, Balboa, Republic of Panama.

As larvae, diurnal moths of the family Uraniidae are the only insects which regularly eat the leaves of *Omphalea* spp. (Euphorbiaceae). They eat nothing else. *Omphalea* and *Urania* have identical distributions - the Neotropics, east Africa, Madagascar, Northern Australia and the Papuan region - which suggests an ancient association. All uraniids undergo regular population explosions and massive migrations. Treating clones of an *Omphalea* vine to different grazing levels and feeding the newly expanded leaves to larvae, produces profound effects on larval development and mortality. Repeated larval grazing on the same plant apparently results in physical and behavioral changes in the adults that survive. The current hypothesis is that changes in the levels of secondary compounds and basic nutrients occur in *Omphalea* leaves as the result of grazing. Thus the plant is both the ultimate and proximate reason why *Urania* migrates.

IMPACT OF INDUCED TREE RESPONSES ON GYPSY MOTH POPULATIONS. J. C. Schultz* and M. Rossiter, Department of Entomology, Penn State University, University Park, PA, USA 16802

Results of field experiments indicate that favored gypsy moth host species can respond to defoliation by lowering leaf quality. Although the form and strength of this response differed between tree species, sites, individuals, and years, it had a negative impact on gypsy moth growth and fecundity and may influence population dynamics. However, some of the induced changes may favor population growth by reducing larval mortality due to pathogens. The net impact of induced tree responses on population dynamics could be positive or negative.

INDUCED RESISTANCE IN AGRICULTURAL SYSTEMS. R. Karban, Department of Entomology, University of California, Davis, California, USA 95616.

There is now well documented evidence that insect damage induces numerous changes in plants. Insect bioassays of these changes show that some have the potential to negatively affect insect population growth. However, several conditions must be met before this potential can be realized in agricultural situations. 1)The induced resistance must be relevant at large spatial scales. 2)Life table differences, found in bioassay results, must not be compensated for at other life stages. 3)The timing of resistance must be appropriate. 4)The initial damage required to induce resistance must not reduce the economic value of the crop. 5)The environmental conditions present must favor resistance.

These conditions are discussed with reference to induced resistance against spider mites in cotton and grape. Resistance may be induced by cultural practices and plant vaccinations may also be possible.

THE IMPACT OF INDUCIBLE PHYTOCHEMICALS ON FOOD SELECTION BY INSECT HERBIVORES AND ITS CONSEQUENCES FOR THE DISTRIBUTION OF GRAZING DAMAGE. P.J. Edwards, S.D. Wratten and R.M. Gibberd, Department of Biology, Building 44, The University, Southampton, SO9 5NH, UK.

A simple laboratory bioassay is described in which leaves are damaged mechanically and, after an interval, picked and fed to a test animal, usually a species of polyphagous lepidopteran. This method has revealed that in a wide range of species damage leads to reduced palatability of both damaged and nearby undamaged leaves. In some species even very small amounts of damage may cause at least locally reduced palatability. These conclusions are supported by field bioassay experiments using the naturally occurring insect herbivore population. We argue that the local reduction in palatability induced by feeding may affect the foraging behaviour of insects and the distribution of feeding damage. An experiment is described to investigate the effects of leaf damage upon foraging and feeding by larvae of *Orthosia stabilis* (Noctuidae). There was greater larval movement on shoots which had been damaged than on controls, but much less feeding. The ecological consequences of such effects, and their possible defensive significance are discussed. We suggest that their significance for the plant is that they lead to a dispersed pattern of grazing, and in particular minimise damage to young leaves.

INDUCED DEFENSES IN SOYBEAN AGAINST LEAF FEEDING INSECTS. M. Kogan* AND Daniel C. Fischer, Office of Agricultural Entomology, University of Illinois, Urbana, Ill. 61820, U.S.A.

Insect phyllophagy on soybean elicits responses ranging from compensatory growth to increased levels of resistance to subsequent herbivory. Soybean responds to physical and biotic stresses by *de novo* synthesis and accumulation of phytoalexins, the most important of which are the isoflavonoid glyceollins. Certain hydroxybenzoic acids, and glyceollin mixtures are feeding deterrents for the oligophagous species *Epilachna varivestis* and reduce food utilization in the polyphagous *Pseudoplusia includens*. Induction of defenses by previous herbivory shown to occur in soybean is tightly related to stage of plant growth and leaf age. Individual plants at any given stage of growth are a mosaic of highly acceptable to unacceptable foliage for those phytophagous species. The role of phenolics and glyceollins in this induced response is being investigated. The relationship between intra-plant variability and phytophagy is not clear so the possible significance of this variability in agriculture is only conjectural at this time.

INSECT GALLS: ADAPTATIONS TO HYGROTHERMALLY STRESSED ENVIRONMENTS ? G.W. Fernandes* & P.W. Price. Brazilian National Research Council (CNPq), Brazil and Department of Biological Sciences, Box 5640, Northern Arizona University, Flagstaff, AZ 86011 USA.

The adaptive significance of insect galls has been discussed in the literature many times, but little emphasis has been placed on testing hypotheses. Three hypotheses were proposed to account for variation in galling species number on shrubs in Brazil and USA. In both geographical regions the harsh environment and the altitudinal gradient hypothesis were supported. Galling species richness increased with increasing hygrothermal stress and decreasing elevation. However, significantly more galls were found in dry sites than in wet sites at the same elevations, thus supporting the harsh environment hypothesis. Free-living insect herbivores showed the opposite distributional trends, i.e., being speciose in wet areas. This emphasized the importance of the galling habit for protection against hygrothermal stress. The ultimate factor driving this pattern is higher survival of larvae in drier sites. The proximate mechanisms being studied are fungal pathogens and parasitoids which cause higher mortalities in wet sites.

ECOLOGY AND POPULATION DYNAMICS OF GALL-FORMING APHIDS: A REVIEW. D. Wool, Department of Zoology, Tel Aviv University, Ramat Aviv 69978, Israel.

Gall-forming species are a minority among the Aphidoidea and occur in 3 families. Each family has a restricted range of primary hosts. During the short period of gall formation, competition among fundatrices may be a major limiting factor of gall density. Within the gall, the fundatrix genotype is multiplied parthenogenetically many times under ecologically favorable conditions, but many of the alate progeny may be lost during subsequent dispersal to the secondary hosts. Parasites and predators sometimes destroy considerable numbers of galls, although some aphids may survive in such galls. Overwintering populations, and alate sexuparae in their return flight to the primary hosts, may also suffer heavy losses. This review will concentrate on the dynamics of clone-size changes within galls and on the distribution and abundance patterns of gall densities in some species of gall-forming aphids, with an emphasis on the genetic implications of their complex life cycle.

THE IMPACTS OF A NEOTROPICAL GALL-FORMING INSECT ON ITS HOST PLANT, *CLUSIA LANCEOLATA* CAMB. R.F. Monteiro, Dept. de Ecologia, I.B., Universidade Federal do Rio de Janeiro, CP 68020, CEP 21941, Rio de Janeiro, Brazil.

We investigated the effects of leaf galls induced by *Gnesiodiplosis* n.sp. (Diptera: Cecidomyiidae) on *C. lanceolata* a very common shrub on Barra de Maricá sand dunes, Maricá, State of Rio de Janeiro, Brazil. Leaf area, wet and dry masses of 44 pairs of galled and non-galled leaves of the same age were measured. Galled leaves had surface area 25% smaller ($p < 0.001$; $t = 5.451$) but had wet and dry masses 120% and 50%, respectively, larger than non galled leaves ($p < 0.001$, $t = 8.432$; $p < 0.001$, $t = 8.363$). The number of galls per leaf was not significantly correlated with final leaf size ($r = 0.11$, NS), but strongly influenced wet and dry leaf masses ($p < 0.001$, $t = 0.737$; $p < 0.001$, $t = 0.632$). Leaf expansion possibly depends on leaf maturity and number of eggs laid. When a large number of larvae begin to develop in the leaf bud, the leaf usually expands very little but becomes very thick, however. It is very difficult to find such kind of leaves in positions below the third pair of leaves, from the top of the branch, in the field. Thus, it is probable that leaf abscission occurs early in these cases. Field experiments, still in process, have confirmed the effect of galls in the reduction of the life span of these leaves.

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ROLES OF GALL FORMATION IN THE POPULATION DYNAMICS OF THE PINE NEEDLE GALL MIDGE, *THECODIPLOSIS JAPONENSIS* UCHIDA ET INOUE (DIPTERA: CECIDOMYIIDAE). K. Soné, Forestry and Forest Products Research Institute, Tsukuba, Ibaraki 305, Japan.

Larvae of the pine needle gall midge live in galls during the first- to third-stage before they leave and jump down to the ground for hibernation. Usually two or more larvae are found in a gall and mortality of larvae in galls was very low. This low mortality contributed to the stepped survivorship curve of this species. The competition among larvae in the galls was not so strong as to cause the death of larvae, but it did decrease larval body size. The decline in the size of larvae might lead to increased mortality of the overwintering population in the soil and to decreases in body size and fecundity of females. The gregariousness of larvae seemed to give a greater chance to settle themselves and to survive in the gall. Galls with more larvae probably produced more females per gall, which resulted in higher fecundity per gall.

EVOLUTIONARY FORCES SHAPING THE WINDOW OF VULNERABILITY FOR A STEM GALLER TO ATTACK BY A PARASITOID. T. P. Craig, Department of Biology, Northern Arizona University, Flagstaff, Arizona USA 86011.

Euura lasiolepis, a stem galling sawfly on the arroyo willow, *Salix lasiolepis*, has a window of vulnerability to attack by the parasitoid *Lathrostizus euurae*. The window - the period when the parasitoid can successfully attack the sawfly - was formed by an interaction of willow and sawfly characters. Gall growth rate was one factor which determined the size of the window. Preliminary evidence indicated gall growth was a heritable trait of the willow but not the sawfly. Galls formed on different willow clones produced different size windows of vulnerability. Sawflies in galls which provided protection against another parasitoid were highly vulnerable to *Lathrostizus* attack. *Lathrostizus* was less efficient in parasitizing *E. lasiolepis* than in parasitizing an alternate host the petiole gall-former, *Euura* sp., also found on the arroyo willow. This suggests *Lathrostizus* has evolved primarily to parasitize hosts other than *E. lasiolepis*.

THE THIRD TROPHIC LEVEL AS A SELECTIVE FORCE IN THE EVOLUTION OF GALL MORPHOLOGY. A.E. Weis*, Section of Ecology and Evolutionary Biology, Northern Illinois University, DeKalb, Illinois 60115, U.S.A.

Galls are a food source for gall-making insects, but many features of gall morphology have no apparent relationship to nutritional status. For instance, in the 'oak apple' galls, formed by cynipids, there is much empty space between the outer tissue layer and the central cavity that holds the developing larva. Such spaces can increase gall radius without changing gall biomass. The importance of this may be that large gall radius deters attack by parasitoids with limited ovipositor lengths. Results from a five-year, 16-population study of attack by *Eurytoma gigantea* on the tephritid *Eurosta solidaginis* shows that attack places a consistent selection pressure favoring gallmakers that induce larger galls. Variation in *Eurosta* gall size is not caused by variation in the size of the nutritive layer, but by variation in the amount of cortex tissue, which consists of large, vacuous and nitrogen poor cells. Thus, optimizing selection may lead to the evolution of gall morphologies that maximize protection from parasitism at a limited cost to the plant.

HOST SPECIFICITY AND DISTRIBUTION OF CANADIAN DIPLOLEPIS (HYMENOPTERA: CYNIPIDAE). J.D. Shorthouse, Department of Biology, Laurentian University, Sudbury, Ontario, Canada, P3E 2C6.

Cynipid wasps of the genus *Diplolepis* induce structurally distinct galls on either the leaves, stems or roots of wild roses (*Rosa* spp.). At least 17 of the 29 endemic North American *Diplolepis* are found in Canada on either *Rosa acicularis* Lindl., *R. woodsii* Lindl., *R. blanda* Ait. or *R. arkansana* Porter. Some species of *Diplolepis* are host specific whereas others are found on several hosts. Two species, *D. spinosa* (Ashmead) (a stem-gall inducer) and *D. radicum* (Osten Sacken) (a root-gall inducer), have recently attacked the introduced shrub rose *R. rugosa* Thunb. in urban habitats. Two introduced Palearctic species, *D. rosae* (L.) and *D. mayri* (Schlecht.), occur in Canada on introduced roses. Factors influencing the distribution of both endemic and introduced species of *Diplolepis*, along with their associated communities of parasitoids, are discussed.

SECONDARY SUCCESSION OF GALL INDUCERS IN COPPICE. H.C. Roskam*, H. de Gier, B. Persoon, G.J. de Bruijn and W.J. ter Keurs, Department of Population Biology, University of Leiden, The Netherlands.

The abundance and diversity of gall inducers have been compared during the summer of 1985 in ten coppice plots ranging in age from one to thirty years. In this study-area, with ashes as dominant trees, twenty gall makers have been assessed on ten plant species: eight gall mites, nine gall midges, two gall wasps and one gall flea. In a principal component analysis the age of the sucker shoots, as indicator for the age of the plots, appeared to be the main factor responsible for the abundance of the gall makers. The interdependence of the age of the suckers and abundance of the various gallers could, in double log transformation, be described with five basically different linear regression functions. The variation in age of suckers appeared to have a positive effect on the diversity of the gall inducing species.

GALLSIZE AND PARASITOID: IMPORTANT FACTORS IN THE EVOLUTION OF PARTHENOGENESIS IN CYNIPID WASPS (HYMENOPTERA: CYNIPIDAE). B. Stille, Department of Zoology, University of Lund, Helgonavägen 3, S-223 62 Lund, Sweden.

The cynipid wasps *Diplolepis rosae* and *D. mayri* are obligate parthenogens. The galls of *D. rosae* are roughly five times the size of those of *D. mayri*. Each species is associated with an inquiline cynipid, *Periclistus brandtii* and *P. caninae*, respectively, which are smaller, less affected by parasitoids, and hatch in larger numbers than their hosts. Compared to *P. caninae*, *P. brandtii* has high average clutch size, female biased sexratio (1:2), high sexratio variance, low genetic variation and a low male thorax/abdomen ratio, suggesting an inbred species with within-gall, pre-dispersal mating. Galls producing only one sex is more common in *P. caninae* (40%) than in *P. brandtii* (15%), and post-dispersal mating and outbreeding is expected in the former.

Even if distorted sexratios are stable strategies and parasitoids may favour bisexuality in their hosts, an increased degree of parasitization of *P. brandtii* may lead to the establishment of parthenogenetic strains. With a pre-dispersal, low male frequency strategy, increased parasitization could increase the frequency of one-sex galls and thus also the frequency of unmated females. This situation, in combination with a low number of deleterious recessives due to previous inbreeding, would favour parthenogenetic females.

SEED PREDATION BY MUTUALISTIC FIG WASPS IN FOURTEEN SPECIES OF AUSTRALIAN FIGS. J.F. Addicott* and J.L. Bronstein, Department of Zoology, University of Alberta, Edmonton, Alberta, Canada, T6G 2E9

The evolution of mutualistic systems is dependent on the relative levels of costs and benefits, but in most mutualistic systems it is difficult to measure and compare costs and benefits. The fig-fig wasp mutualism is one in which costs and benefits can be easily compared.

Syconia were collected from fourteen of the nineteen species of monoecious figs in Australia. Fig wasps were reared from each syconia. Counts were then made of the number and sex of all wasps (primarily Agaonidae and Torymidae), and the number of seeds that were mature, aborted or destroyed by fig wasps.

Comparisons will be presented on the levels of seed predation by both pollinating and non-pollinating fig wasps between these fourteen Australian figs, other published data on figs, and other pollination-seed predation mutualisms.

The Role Of Insects In Structuring The Heterotroph Communities In Decomposing Trees

DEAD TREE ARTHROPODS: ADVANCED OR PRIMITIVE? W. D. Hamilton, Department of Zoology, University of Oxford, South Parks Road, Oxford OX1 3PS, United Kingdom.

The fauna of dead trees is less speciose but more diverse at high taxonomic levels than fauna of leaves and living parts. Likewise, a high proportion of open-air insect groups have a primitive dead tree basal branch. The question arises, are dead trees store rooms or forcing houses of insect evolution?

INTERACTIONS BETWEEN THE SOUTHERN PINE BEETLE, PINE ENGRAVER BEETLES AND CERAMBYCIDS IN SOUTHERN PINES. R.O. Flamm and R.N. Coulson, Department of Entomology, Texas A&M University, College Station, Texas USA 77843.

The manner in which a group of bark beetles (Coleoptera: Scolytidae) and a wood borer (Coleoptera: Cerambycidae) co-exist in pine phloem was studied. The wood borer, *Monochamus titillator*, is a significant mortality factor for the bark beetles. The bark beetles, however, have little direct contact with *M. titillator* and therefore are able to maintain a significant presence in this community. In contrast, commensalism, through the expansion of *M. titillator*'s resource base caused by bark beetle activity seems to be important in maintaining *M. titillator*'s place in this community.

SEX PHEROMONES OF WOOD-BORING ANOBIID BEETLES: CROSS ATTRACTION AND POSSIBLE EFFECTS ON PREDATORS AND PARASITOIDS. P.R. White* and M.C. Birch, Dept. of Zoology, South Parks Rd., Oxford OX1 3PS. U.K.

Behavioural, electrophysiological and chemical studies have shown that several species of anobiid beetles use female-produced sex pheromones for mate location. The common furniture beetle, *Anobium punctatum*, and the drug-store beetle, *Stegobium paniceum*, appear to use the same sex pheromone, and considerable cross attraction occurs in behavioural assays. The fan-bearing wood borer, *Ptilinus pectinicornis*, uses a different single component pheromone, whilst the death watch beetle, *Xestobium rufovillosum*, shows no evidence of using sex pheromones for mate location.

Amongst pheromone-producing species different strategies occur. *A. punctatum* and *S. paniceum* females produce relatively large amounts of pheromone and males have simple, filiform antennae. *P. pectinicornis* females produce very little pheromone, however, whilst the males have elaborate pectinate antennae. A possible explanation of this divergence may be selection exerted by parasitoids or predators locating beetles by the emitted pheromone.

INSECT-MEDIATED COMMUNITY DEVELOPMENT AND DECOMPOSITION IN CONIFER LOGS IN THE PACIFIC NORTHWEST. T. D. Schowalter*, J. D. Lattin, R. G. Kelsey, S. E. Carpenter, E. R. Ingham, M. E. Harmon and A. R. Moldenke, Department of Entomology, O.S.U., Corvallis, OR 97331-2907.

Fallen trees initially are protected from microbial decomposers by the physical-chemical barrier provided by bark. Insects, especially bark beetles and ambrosia beetles, are instrumental in penetrating this barrier and inoculating the log with a massive dose of mutualistic and opportunistic microflora and microfauna. Community development and biological activity are shaped subsequently by species interactions within a changing physical-chemical environment. Insect galleries constitute biological "hot spots", sites of rapid substrate degradation and nutrient mobilization, and provide conduits for import and export of organisms and nutrients. Major changes in community structure and substrate degradation accompany the arrival of termites and their associated microflora.

STRUCTURE OF THE WESTERN PINE BEETLE COMMUNITY. D.L. Dahlsten, T.J. Eager*, and D.L. Rowney, Division of Biological Control, University of California, Berkeley, California 94720, U.S.A.

Arthropod communities centered upon the attack and utilization of host trees by the western pine beetle (*Dendroctonus brevicomis*), have a complex trophic and temporal structure. Various predators and parasitoids attack all life stages of the western pine beetle, significantly affecting the population dynamics of this community. The condition of the host tree also plays an important role in the structure of this ecosystem. It has been demonstrated that hosts weakened by the influence of photochemical smog and root disease are less resistant to pine beetle attack, thus allowing the pine beetle population to reach high levels. The stand condition and the interactions among the predators, parasitoids and other associated insects influence the abundance and distribution of the western pine beetle.

RESOURCE HETEROGENEITY AND THE STRUCTURE OF ARTHROPOD ASSEMBLAGES IN PHYTOTELMATA. S. Naeem, Department of Zoology, University of California, Berkeley, CA 94720, U. S. A.

In three phytotelmata systems, experimental and natural heterogeneity of resources leads to heterogeneity in the structure of the arthropod assemblages that inhabit them. The three systems studied were: (1) 2 spp. of arthropods inhabiting Darlingtonia californica, the California pitcher plant; (2) 3 spp. of arthropods inhabiting Heliconia wagneriana in Costa Rica; and (3) 6 spp. of arthropods inhabiting H. imbricata also found in Costa Rica, C. A. Results from this study show that resource-mediated interactions, such as competition or facilitation, may indeed be important in structuring phytotelmata communities, but the effects of such interactions are strongly dependent on the actual levels of resources. Such effects, though important, may nevertheless be difficult to detect when resources are heterogeneous. Conclusions from this study can be extended to shed light on the general debate among community ecologists over the relative importance of interspecific competition in structuring biological communities.

INTERACTION OF THE MOSQUITO, Aedes geniculatus, WITH OTHER TREE-HOLE ARTHROPODS IN SOUTHERN BRITAIN. W. E. Bradshaw* and C. M. Holzapfel, Department of Biology, University of Oregon, Eugene, OR 97403, USA.

In southeastern Britain, Aedes geniculatus shares its tree-hole habitat with two other common mosquitoes, Culex torrentium and Anopheles plumbeus, and with two principal benthic arthropods, the helodid beetle, Prionocyphon serricornis, and the chironomid midge, Metriocnemus martinii. Censuses of tree holes during the spring and summer reveal that all of these species segregate their habitat usage in space and time. Manipulations of larval densities to force and increase interspecific encounter show that little interaction occurs between Aedes geniculatus and the other tree-hole arthropods. At the same time, Aedes geniculatus remains resource limited. Thus, macro- and micro-habitat segregation are sufficient to explain the coexistence of mosquito species and of Aedes geniculatus with the benthic fauna.

POPULATION DYNAMICS OF BROMELIAD-INHABITING AQUATIC STAGES OF Wyeomyia vanduzeei (DIPTERA: CULICIDAE). J.H. Frank* and J.C. Allen, Entomology & Nematology Department, 3103 McCarty Hall, University of Florida, Gainesville, Florida 32611, USA, G.A. Curtis, Indian River Mosquito Control District, P.O. Box 670, Vero Beach, Florida 32961, USA, and J.T. Rickard, Orincon Corp., 3366 N. Torrey Pines Court, Suite 320, La Jolla, California 92037, USA.

Eggs, larvae and pupae of Wyeomyia vanduzeei Dyar & Knab occur throughout the year in water-impounding leaf axils of the bromeliad Tillandsia utriculata L. in southern Florida. The rainfall pattern in the vicinity of Vero Beach, Florida, may be modelled at several levels. The most simplified model is a curve of negative skewness with periodicity of 52 weeks: the same curve models the numbers of instar III larvae. A more detailed model shows that rainfall typically is trimodal, with peaks of successively increasing amplitude in February, June, and October, spaced at intervals of about 17 weeks: this rainfall periodicity is imparted to the numbers of mosquito pupae, and therefore to the production of adult mosquitoes.

THE IMPORTANCE OF INTERACTIONS BETWEEN THE PARASITIC CILIATE, LAMBORNELLA CLARKI AND THE MOSQUITO, Aedes sierrensis ON THE COMMUNITY STRUCTURE OF CALIFORNIA TREE-HOLES. J. O. Washburn* and J. R. Anderson, Department of Entomology, University of California, Berkeley, USA 94720.

Aedes sierrensis and L. clarki are widespread inhabitants of treeholes on the west coast of North America. Most treeholes support dense larval populations that are subject to food limitation and intense intraspecific competition. In nature, larval feeding can eliminate populations of microbial prey from treehole water. Lambornella escapes predation by parasitizing their would-be predator. Larvae release a waterborne factor that induces morphogenesis of free-living L. clarki; induced ciliates transform into parasitic cells that encyst on larval predators. Ciliates penetrate the cuticle and enter the hemocoel where they multiply and ultimately kill their host. In nature, larval populations are reduced or eliminated by multiple parasite cycles which occur over the prolonged period of larval development. In addition to modulating the number of emerging adult mosquitoes, facultative parasitism by L. clarki relaxes larval predation pressure allowing for increases in populations of protozoans and other microorganisms.

COMPETITION AND PREDATION IN DIPTERA IMMATURES INHABITING NEPENTHES PITCHERS IN MALAYSIA. M. Mogi* (Department of Microbiology, Saga Medical School, Saga 840-01, Japan) and H.S. Yong (Department of Zoology, Faculty of Science, University of Malaya, 59100 Kuala Lumpur, Malaysia).

Beaver (1983) compiled the knowledge on the fauna in Nepenthes pitchers, and has analysed community structure in this habitat. Despite Beaver's excellent works, our knowledge is still limited with respect to Nepenthes species and locality. We studied arthropod faunas in pitchers of Nepenthes ampullaria in Malacca (Malay Peninsular) and Kuching (Sarawak) and N. macfarlanei at two isolated highlands (Malay Peninsular). The data are analysed for (1) variation of community structure, (2) intra- and inter-specific competition among dipteran larvae, and (3) effects of predation on survival of dipteran prey.

SEXUAL SELECTION AND PROTANDRY IN THE WESTERN TREEHOLE MOSQUITO, Aedes sierrensis (DIPTERA: CULICIDAE). W.A. Hawley, Department of Biological Sciences, University of Notre Dame, Notre Dame, Indiana, U.S.A. 46556.

Aedes sierrensis in Oregon exhibits extreme protandry: in 3 successive years the median date of pupation of males preceded that of females by 17, 28 and 12 days. Protandry in A. sierrensis is affected by climatic and biotic limitations, with the reproductive consequences of size variation in both sexes of additional importance. Eggs hatch after rains begin in late fall; by late summer most treeholes have dried up. Winters are sufficiently cold to freeze small holes about 1 year in 3 and all holes about 1 year in 7.5. While freezing might appear to select for late hatching, individuals that hatch late may die due to treehole desiccation or may encounter more severe intraspecific competition, pupate at lower weights, and consequently realize reduced fitness. Larger, early-emerging females are up to 30 times more fecund than those emerging later. Since the resource tracked by males is, strictly, potential future offspring rather than females per se, the extreme protandry exhibited by this species is largely based on failure to consider this size-based variation in lifetime expected female fecundity.

Plant-held Waters: Vector Sources, Centres Of Speciation And Model Communities

HISTORICAL ECOLOGY OF ASTIGMATID MITES INHABITING PHYTOTELMATA. B.M. O'Connor* and R.F.C. Naczi, Museum of Zoology and Department of Biology, The University of Michigan, Ann Arbor, Michigan 48109, USA

The Astigmata is the most diverse group of mites inhabiting phytotelmata. Within the group, at least four independent lineages contain species from such habitats. The most diverse clade comprises a new subfamily in the Histiostomatidae and includes the genera *Hormosianoctus* from tree holes and Bromeliaceae, *Sarraceniopus* from Sarraceniaceae, *Zwickia* and *Creutzeria* and unnamed taxa from Nepenthaceae, and unnamed taxa from Araceae and Musaceae. The second clade comprises the entire family Algophagidae, inhabiting sap fluxes, tree holes, *Heliconia* (Musaceae) bracts and permanent aquatic habitats. The third group, also in the Histiostomatidae, includes some species of *Histiostoma* from tree holes and possibly permanent aquatic habitats. Finally, the genus *Naiadacarus* (family Acaridae) inhabits tree holes, although an undescribed species is possibly associated with wet subcortical habitats. Known species in each lineage disperse via phoretic associations with Diptera or Coleoptera.

STABILITY OF TREEHOLES AND PERIODICITY OF THEIR MOSQUITO FAUNA. L.P. Lounibos, Florida Medical Entomology Laboratory, University of Florida, Vero Beach, Florida 32962 USA.

Most phytotelmata are regarded as ephemeral habitats for aquatic insects, but some water-containing treeholes provide an exception to this generalization. Certain treeholes in southern Florida examined for ten successive years by fortnightly census-replacement continuously harbored larval and pupal stages of four species of mosquito, except during infrequent droughts. Time series analyses revealed periodicities in culicid abundance particular to each species. Temporal patterns of mosquito occurrence and productivity are interpreted in light of climatic factors, habitat stability, larval food, predation, and density dependence.

DETERMINISM OR CHANCE, ENVIRONMENTAL CONTROL OR BIOTIC INTERACTION: THEORETICAL BASES FOR EXPLAINING COMMUNITY STRUCTURE IN TREEHOLES. R.L. Kitching¹ and S.L. Pimm², ⁽¹⁾Department of Ecosystem Management, University of New England, Armidale, NSW, Australia; ⁽²⁾Graduate Program in Ecology, University of Tennessee, Knoxville, Tennessee 37996-1610, USA.

A variety of theoretical models exist which have been used to explain community structure at a variety of levels. These include the energy-constraints and dynamic constraints hypotheses to account for food-chain lengths; the appeal to stochastic processes as an explanation of foodweb structure; and, various explanations based on competitive and predatory processes as structuring mechanisms in communities. We have argued elsewhere that communities in phytotelms provide excellent vehicles for distinguishing among such hypotheses. We have good information on the foodwebs from water-filled treeholes in the UK, Germany, various locations in continental North America, Sulawesi, New Guinea, and a number of sites in subtropical and temperate Australia, either collected by us or collated from the literature. Using this data base we suggest that the relevance of deterministic as opposed to stochastic processes in accounting for the length of food chains (and indeed the complexity of foodwebs overall) reflects the scale of observation, with chance processes playing a much more important role at the local level than at the regional scale. Biotic processes are probably most appropriate for accounting for 'species packing' levels.

ECOLOGY OF ASTIGMATID MITES INHABITING WATER-FILLED TREEHOLES. N.J. Fashing. Department of Biology, College of William and Mary, Williamsburg, Va., U.S.A. 23185.

Six species of astigmatid mites are known to inhabit water-filled treeholes: *Naiadacarus arboricola* (Acaridae), *Hormosianoctus mallotae* (Histiostomatidae), *Algophagus pennsylvanicus* (Algophagidae) (all from eastern North America), *Naiadacarus oregonensis* (Acaridae) (from western North America), and two undescribed species of Algophagidae from eastern Australia. Such mites are absent from this habitat in western Europe, and it is not known if any occur in other parts of the world. Ecological studies have been conducted only on those species from eastern North America. The coexistence of *N. arboricola* and *A. pennsylvanicus* in a treehole is not uncommon, however it is rare to find all three species present. Functional morphology of the mouthparts and feeding behavior indicate *N. arboricola* is a shredder and feeds by skeletonizing decomposing leaves, *A. pennsylvanicus* grazes on fungi, and *H. mallotae* is a filter feeder. Life history studies indicate all are probably K-selected species. Dispersal in *H. mallotae* and *N. arboricola* is accomplished by a facultative deutonymphal instar and both utilize members of the syrphid fly genus *Mallota* as dispersal agents. The mechanism of dispersal in *A. pennsylvanicus* is unknown.

STRUCTURE OF AQUATIC INSECT COMMUNITIES INHABITING TWO *HELIAMPHORA* PITCHER-PLANT SPECIES OF THE VENEZUELAN HIGHLANDS. D.Fish*, Medical Entomology Laboratory, Department of Medicine, New York Medical College, Valhalla, New York, USA, 10595 and R.Barrera, Instituto de Zoología Tropical, Universidad Central de Venezuela, Apartado 47058, Caracas 1041, Venezuela.

Samples of water-filled leaves of 2 insectivorous pitcher plant species (Sarraceniaceae) were studied: *Heliamphora heterodoxa* from the Gran Sabana (elevation =1400 m) and *H. nutans* from Mt. Roraima (el.=2700 m). A community comprised of only 2 aquatic insect species was found to inhabit each plant species. In each case, the mosquitoes *Wyeomyia fishi* Zavortink (Diptera: Culicidae) in *H. heterodoxa* and *W. zinzala* Zavortink in *H. nutans* numerically dominated an unidentified chironomid species.

The successional pattern of insect species is similar to that observed in nearctic *Sarracenia purpurea* with mosquitoes appearing earlier than chironomids, but species richness is poorer in these neotropical communities.

RECRUITMENT PATTERNS AND THEIR INFLUENCE ON RESPONSE TO LARVAL COMPETITION IN *AEDES TRISERIATUS* (DIPTERA: CULICIDAE). T. Lvdahl*, M.J. Firko and J.S. Edgerly, Department of Biology, Clark University, Worcester, Massachusetts 01610, USA.

Eggs of *Aedes* mosquitoes frequently exhibit variation in the timing of egg hatching, which establishes the possibility for overlap between larvae of different developmental stages, including competition and cannibalism, as well as inhibition of hatching under crowded conditions. Each of these interactions has potential consequences to the tracking of resources by a population. The occurrence of egg hatching inhibition in natural habitats is demonstrated by the creation of fixed densities of *Aedes triseriatus* larvae, which resulted in reduced hatching rates of egg batches inserted into treeholes. We manipulated the pattern of larval recruitment in simulated field habitats, and compared the responses of populations to resource shortages. Two groups were established with single cohorts of newly-hatched larvae at low (18 larvae/ jar) and high (118 larvae/ jar) densities. Two groups were established with a pattern of larval recruitment, beginning with an initial cohort of 18 larvae followed by 4 additional cohorts of 25 larvae added at 4-day intervals. Added larvae were either freshly-hatched (<3 h) or one day old. A fifth group was established with an initial cohort of 18 larvae, followed by 4 successive cohorts of 25 eggs each, added at 4-day intervals. Preliminary analyses indicate that groups formed by staggered recruitment, in the form of either eggs or larvae, were more successful by all measures (adult size, development time, survivorship) than groups of the same size initiated by a single cohort of larvae. For the added cohorts, no significant differences in survival can be found between the newly hatched and day-old larval recruitment groups, suggesting that cannibalism was not an important factor in these conditions. Cohorts added in the form of eggs survived to adult emergence in higher numbers than cohorts added as larvae, suggesting that the timing of egg hatching may correspond with favorable conditions for newly hatched larvae.

THE MARSH BEETLE FAUNA (COLEOPTERA: SCIRTIDAE) INHABITING PHYTOTELMATA: A REVIEW OF OUR PRESENT KNOWLEDGE. D.K. Young* and J.B. Stribling, Department of Entomology, University of Wisconsin, Madison, Wisconsin 53706.

Scirtid larvae have been recorded from ground pools, marshes, sphagnum bogs, and lentic microhabitats within rivers and streams such as marginal pools and backwaters. They are also characteristic, though poorly studied, components of phytotelmata: small lentic communities passively formed from water collecting in parts of plants. Among phytotelmata examined thus far, scirtid larvae are particularly abundant in aquatic tree holes and water collecting bromeliads. The most commonly encountered tree hole scirtids belong to the genus *Prionocyphon*; additional records include species of *Cyphon* and *Flavohelodes*. Scirtids associated with bromeliad phytotelmata belong to the genera *Elodes*, *Scirtes* and *Cyphon*. Unidentified scirtid larvae have also been associated with other types of phytotelmata, including stems and stalks of bamboo and bananas and foliar sheaths of Pandanaceae.

EFFECTS OF HABITAT FRAGMENTATION ON THE SOIL SURFACE ARTHROPOD COMMUNITY IN A SOUTH GERMAN HEATHLAND.

M. Dieterich, Department of Entomology, Oregon State University, Corvallis, Oregon 97331, USA.

Pitfall trapping was used to compare the arthropod community in open pasture with that in areas fragmented by early stages of forest succession. Data were collected for 2 seasons on a 2.5 hectare study site in a dry grassland at the edge of the Suevoian Alb mountains. Using a trap which allowed live capture of the animals, Carabidae, Staphilinidae and Orthoptera were determined to the species level. Other arthropods were identified to genus or family.

Adults of 3 and larvae of 2 carabid species, as well as 3 species of Staphilinidae and 2 species of Orthoptera were found to be most common in open grassland areas. For Carabidae Renkonen indices showed highest similarities between study plots in open pasture (80.5%) and between sites fragmented by woody vegetation (79.4%). Indices were lower comparing open to fragmented sites. Similar trends were observed for Staphilinidae. In some species different areas were used depending on life stage or time of the year. Other factors that affected species abundance and distribution were vegetation density, abundance of grass tussocks and ant density. Shrew predation also was important in the hedges.

COMMUNITY STRUCTURE OF FLOWER-VISITING INSECTS (HYMENOPTERA APOIDEA, LEPIDOPTERA, DIPTERA) IN DIFFERENT GRASSLAND TYPES OF SOUTHWESTERN GERMANY. A. Kratochwil, Inst.Biol.II, Univ.of Freiburg, Schänzlestr. 1, D-7800 Freiburg, FRG.

Inside a small vegetation mosaic of 10 acres the different plant communities (Xerobrometum, Mesobrometum, Molinietum, Arrhenatheretum) are characterized by special communities of flower visitors. Seen in the light of biogeography plant communities with a high percentage of submediterranean plant species (Xerobrometum, Mesobrometum) own a flower visitor community consisting of many species with submediterranean distribution. In the same study area the Arrhenatheretum is characterized by a high percentage of Central European and Eurosiberian plant species and the flower visitors are predominantly of the same geoelement. Flower-visiting insects from special area-types prefer to gather nectar and pollen from those plant species and plant communities which belong to their own geoelement. Even insects with a high flight capacity use this pattern in the study area. The community structure based on the historical processes of the flora and fauna is similar to that of subsystems with identical areageographical origin.

SOIL INVERTEBRATES IN THE CANOPIES OF TROPICAL CLOUD FORESTS. M. G. Paoletti*, D. H. Stinner and B. R. Stinner, Department of Biology, University of Padova, Padova, Italy.

Communities of invertebrates were quantified in epiphytic and suspended soils of a Venezuelan cloud forest at Rancho Grande National Park at two locations, relatively wet and dry sites. Invertebrates from these canopy soils were compared to those animals inhabiting the forest floor. Invertebrate (earthworms, isopods, millipedes, spiders, beetles and ants) density was greater in the canopy than the forest floor environment for both sites. However, the difference in invertebrate density between the canopy and forest floor habitats was greater in the wet site. These results are discussed in terms of organic matter dynamics and nutrient cycling processes.

COMMUNITY STRUCTURE OF THE ARTHROPOD FAUNA OF TROPICAL TREES AND AN ANALYSIS OF THE GLOBAL DIVERSITY OF THE INSECTA. N.E. Stork, Department of Entomology, British Museum (Natural History), Cromwell Rd., London SW7 5BD, U.K.

Use of knockdown insecticides in S.E. Asian tropical trees has provided samples of their arthropod fauna. These samples have been analysed to investigate the structure of the arthropod community associated with trees in terms of numbers of individuals, species, biomass and body size. Variation in the community structure with forest type, season and altitude are also considered. Erwin's global estimate of 30 million species of insects in tropical forests is reanalysed using this new data.

GUILD STRUCTURE AND DYNAMICS IN CYNIPID PARASITOID FAUNAS.

Michael J. Crawley* and Rosemary Hails, Department of Pure and Applied Biology, Imperial College at Silwood Park, Ascot, Berkshire, SL5 7PY, England.

The cynipid gall fauna of *Quercus robur* provides an attractive group for studies on guild structure and dynamics. Differences in the relative abundance of different gall species are predictably related to host-plant phenotype. While none of the parasitic enemies of the cynipids are strict specialists, almost all of them show distinct preferences for one species. Changes in relative abundance have occurred following the introduction of two cynipid species from Southern Europe. Two species, the knopper gall of acorns (*Andricus quercuscalicis*) and *Andricus lignicola* have increased in abundance since the early 1960s to form perhaps the most conspicuous element of the gall fauna in Southern England. The relationship between these two species and the resident guild of parasitoids is described, along with the extraordinary sex ratios exhibited by those parasitoids which attack the sexual generation of *Andricus quercuscalicis* on Turkey Oak (*Quercus cerris*). The parasitoids attacking these small galls produce virtually 100% male progeny. This behaviour is examined in the light of theories relating to optimal sex ratio determination.

SYMPATRIC SPECIATION IN INSECT PARASITOIDS ASSOCIATED WITH GALL MAKERS OF THE EUROPEAN BEECH. K.-H. Lampe, Abt. Entomologische Parasitologie, Museum Alexander Koenig, Adenauerallee 150-164, D-5300 Bonn 1, W. Germany.

In the course of their evolution from free, external feeders to gall formers phytophagous insects have lost some of their original, typical parasitoids. The recent gall makers have instead acquired new polyphagous parasitoids of other phytophagous insect groups with similar life forms. The European beech, *Fagus sylvatica* L., harbors only a few species of phytophagous insects, e.g. the systematically isolated Cecidomyiidae *Mikiola fagi* Htg. and *Hartigiola annulipes* Htg. The Cynipidae and other gall makers are missing completely. *M. fagi* and *H. annulipes* are exploited by 3-4 species of *Aprostocetus* and by 3-4 species of *Torymus* each. The parasitoid complex of these gall midges of the European beech can best be interpreted by likening it to radiation processes on very remote islands.

THE EFFECT OF EXPERIMENTAL MANIPULATIONS OF SUBMERSED MACROPHYTES ON THE CHIRONOMID (DIPTERA: CHIRONOMIDAE) COMMUNITY OF A FRESHWATER MARSH. Dale A. Wrubleski, Department of Entomology, University of Alberta, Edmonton, Alberta, T6G 2E3.

The objectives of this study were to determine: 1) how the presence or absence of submersed macrophytes affects chironomid community structure, 2) how submersed macrophytes alter the environmental parameters of their surrounding environment, and 3) how these altered environmental parameters affect the chironomid community. Sago pondweed (*Potamogeton pectinatus*) was either removed via clipping or permitted to grow in fenced 5 x 5m plots in a shallow freshwater marsh in south-central Manitoba. Chironomids were sampled with floating emergence traps and benthic cores. Dissolved oxygen, temperature, pH, and epipelic, epiphytic and planktonic algal biomass were the environmental parameters monitored.

Total chironomid emergence was only slightly higher from the vegetated plots. Chironomid species composition did not differ between treatments but abundances of individual species did differ significantly. *Corynoneura* cf. *scutellata* and *Tanytus punctipennis* were the most abundant chironomids in the vegetated and denuded plots, respectively. Epipelic, epiphytic and planktonic algal biomass, as well as dissolved oxygen and temperature, had lower values beneath the dense bed of pondweed. Submersed vegetation provides habitat for epiphytic chironomids, but by modifying environmental properties on the bottom, has a negative impact on benthic species. Benthic core samples are currently being analyzed for comparison with emergence trap results.

STRUCTURING OF PINE FOREST ANT COMMUNITIES. R. Savolainen, Department of Zoology, University of Helsinki, P. Rautatiekatu 13, 00100 Helsinki, Finland.

The competition hierarchy of ants, based on differences in their social organization, allows predictions on probable and improbable species pairs. The top-ranking, territorial species of the hierarchy defend their nest, food resources and foraging area. The intermediate, encounter species defend their nest and food resources, but the lowest-level, submissive species only their nest. Due to their aggressive behaviour the territorials and encounterers are not expected to coexist, but the nonaggressive submissives may survive close to the nests of superior species.

I tested the expectations with bait experiments by studying the activity, foraging efficiency and bait preference of the submissive and encounter species in presence of territorial species. I investigated the effect of the territorial species on the use of habitat and vertical layer of the vegetation, and on nest distribution of the encounter and submissive species within the territory. Additionally, I studied colony success of the submissive *F. fusca* as a function of distance from mounds of territorial wood ants.

The encounter species showed complementary occurrences with the territorials. The nest density and number of foragers of the submissive *F. fusca* decreased towards the wood ant mound (complementary abundances), and production of both sexuals and workers was reduced. The abundant *Myrmica* species nested also close to the mounds of territorial species; the myrmicine morphology allowed them to shift to the litter. Due to their smallness and intimidating behaviour the *Leptothorax* species could associate with the territorial species.

GUILD STRUCTURE AND DYNAMICS OF SCARABAEID DUNG BEETLES.

(1) INTERSPECIFIC COMPETITION BETWEEN *ONTHOPAGUS LENZII* AND *LIATONGUS PHANAEOIDES* (COLEOPTERA, SCARABAEIDAE). YASUDA, H. Laboratory of Applied Entomology and Nematology, Faculty of Agriculture, Nagoya University, Nagoya 464, Japan.

Fifteen species of scarabaeid dung beetles coexist in cattle dung at a pasture in Central Japan. I focused on two dung beetle species, *O. lenzii* and *L. phanaeoides*, which have a similar oviposition mode and period, and investigated intra- and interspecific competition for oviposition sites and its effect on the population density of the two species. Population densities (mean number of individuals per dung pat) of the two species were kept relatively stable for five years. Although the fecundity of *L. phanaeoides* (19.0 ± 11.9 ; $n=24$) was twice that of *O. lenzii* (7.7 ± 5.0 ; $n=26$), the population density of *O. lenzii* (57.9) was always higher than that of *L. phanaeoides* (6.1). Experiments with dung pats, in which given numbers of adults of the two species were introduced, showed that the fecundity of *L. phanaeoides* decreased with increase in the density of *O. lenzii*; *L. phanaeoides* oviposited 23.5 ± 5.4 ($n=8$) eggs in a pat where there were no adults of *O. lenzii*, on the other hand, 5.5 ± 0.5 ($n=4$) eggs in a pat where the number of adults of *O. lenzii* was 64 per pat. During reproductive period of *L. phanaeoides*, population density of *O. lenzii* was, actually, more than 60, and *L. phanaeoides* oviposited 2.6 ± 2.5 ($n=56$) eggs per pat in the field. Survival rate from egg to adult was not so different between the two species. There was a negative correlation ($r=-0.49$, $p=0.4$) between population densities of the two species. From these results, I consider that one of the reasons of low population density of *L. phanaeoides* is density effect of *O. lenzii* on the fecundity of *L. phanaeoides*.

COMPETITION AND COEXISTENCE IN A GUILD OF MONOPHAGEOUS GALL-FORMING INSECTS ON THE COMMON REED, *Phragmites australis*. L. De Bruyn, Laboratorium voor Algemene Dierkunde, Rijksuniversitair Centrum Antwerpen, Groenenborgerlaan 171, B-2020 Antwerpen, Belgium.

A study was made on the role of competitive interactions in the niche realisation in a guild of stem-boring flies of the Palaearctic genus *Lipara* (Diptera, Chloropidae). These flies are strict monophagous herbivores of the common reed, *Phragmites australis* (Cav.) Trin. ex Steud., whereupon they cause the well known typical cigar- or spike like galls. Only one larva can develop on one reedshoot. In Belgium, three *Lipara* species can be found, viz. *Lipara lucens* Weigen, *Lipara pullitarsis* Doskocil & Chvála and *Lipara rufitarsis* (Loew).

The species of the stem-boring guild partition resources by shootsize characteristics. Although the potential for competition is high between at least two of the *Lipara* species, and they indeed may be exposed to competitive interactions under exceptional circumstances, our results suggest that competition is of no importance in the niche realisation of the species in this guild.

COEXISTENCE OF COMPETITORS WITH CORRELATED DISTRIBUTIONS AMONG PATCHES. D.W. Tonkyn, Department of Biological Sciences, Clemson University, Clemson, SC, USA 29634

Many insect populations are dispersed each generation in a random or aggregated fashion among ephemeral patches of habitat such as hosts, host plants, or carrion. Recent theoretical work has shown that this fact alone can promote the coexistence of competing species, by providing virtual refugia for each in patches lacking the other. This work has assumed for simplicity that each species is distributed among patches independently of the others although, in nature, positive correlations might be expected for numerous reasons. I present a model of the more general case in which two species are each distributed in a random or aggregated fashion among patches, but with a correlation coefficient between them that can be tuned from 0 to 1. The effects of varying this parameter on the magnitude and stability of population densities will be discussed.

ESTIMATING CARABID SPECIES RICHNESS AND DIVERSITY FROM PITFALL TRAP CATCHES. G.L. Lövei, L. Grüm and A. Dobrovolszky, Department of Zoology, Plant Protection Institute, Hungarian Academy of Sciences, P.O. Box 102, H-1525 Budapest, Hungary.

The number of carabid species was estimated from three samplings in Poland and Hungary. Empirical species-sample curves were created using accumulated numbers of species compared with numbers of pitfall traps. The equilibrium equation of island biogeography co-varied significantly ($r=0.995-0.999$) with the empirical curves. The number of carabid species estimated by 80 traps in Kampinos Forest, Central Poland was 20 in spring and 25 in autumn. An apple orchard near Budapest, Hungary, had a more rich carabid fauna (106 species, 100 traps). Three indices of diversity (dominance, Shannon-Wiener, Q) were tested for the effect of sampling effort on their performance. The Q-index reached the value characteristic for the assemblages at low trap numbers, the other two indices varied widely and did not stabilize as trapping effort increased.

INSECT POPULATIONS AND THEIR USE OF FOOD RESOURCES. J.P. Dempster, Institute of Terrestrial Ecology, Monks Wood Experimental Station, Abbots Ripton, Huntingdon, PE17 2LS, UK.

There is a commonly held belief among ecologists that most insect populations occur at levels well below those at which food supply is limiting. This idea stems from the fact that many species appear to exist at such low densities that they make use of a very small part of the available food. Recent research suggests that this is an oversimplified view of the availability of food resources. Most insects are highly selective in their choice of food, and the food is often highly variable in quality, both spatially and temporally. Many species have difficulty in finding adequate food supplies during the dispersive stages of their life cycles, and this can set limits to the size of their populations.

These views are discussed in light of current work at Monks Wood on the interaction between the orange-tip butterfly and its food plant Cardamine pratensis.

SEASONAL FOOD LIMITATION OF DETRITIVOROUS STREAM INSECTS: AN EXPERIMENTAL TEST. John S. Richardson, Department of Zoology, University of British Columbia, Vancouver, BC, Canada, V6T 1W5.

Many species of stream insects gain most of their body mass from consumption of coarse detritus (>1 mm diam.), however the standing crop of this food material may vary over two orders of magnitude on an annual basis. While the standard explanation is that the life cycle phenology of these organisms is "adapted" to make maximal use of this food while it's abundant, observation indicates that some species may be seasonally food limited. To test this hypothesis, I experimentally manipulated detritus input rates to otherwise natural communities of stream benthos using a replicated, 4-treatment design. Increasing detrital standing crops had significant effects on a number of demographic parameters and behaviour (drift) for many of the detritivores in this 2nd order, coastal stream. Increases in growth rate, survivorship and size at emergence (as an estimate of fitness) all indicate that individual and population growth of these detritivores are food limited. While immigration rates did not differ among treatments, emigration rates were lower when detritus was increased, representing colonization of food-rich patches.

CHAOS, SPATIAL DENSITY-DEPENDENCE AND THE DYNAMICS OF NATURAL ENEMY POPULATIONS. J.C. Allen, Department of Entomology/Nematology, University of Florida, Gainesville, Florida, U.S.A. 32611.

Recent studies of nonlinear dynamic systems have revealed that extremely complicated dynamic motion can come from very simple models. Natural enemy population models (host-parasite, predator-prey, host-pathogen) fall very neatly into this class of behavior, the primary ingredients being nonlinear equations with time lags and/or periodic forcing from the environment. These elements all seem quite realistic and yet they are the primary cause of chaos or unpredictable dynamics in these kinds of models.

The next level of realism is some sort of simple recognition of the spatial dimension. A likely scenario is that animals will respond in a nonlinear ("density-dependent") way to density of their own or other species with whom they interact strongly. Chaos appears to be even more likely in the "local" spatial window in the presence of spatial density-dependence.

SPATIAL ANALYSIS OF THE RELATIONSHIP OF GRASSHOPPER POPULATION DENSITY TO SOIL TYPE. D.L. Johnson, Agriculture Canada Research Station, Lethbridge, Alberta, Canada T1J 4B1

The relationship of grasshopper population density to soil type and texture was investigated for a 114,150 km² area in southern Alberta. Grasshopper abundance over the last 10 years was higher in certain soil zones than in others. Similar relationships have been attributed in some previous studies to soil texture (intrinsic hypothesis). Alternatively, the effect may be due to geographical covariables such as weather, vegetation and farming practices (extrinsic hypothesis).

A geographic information system was utilized to test these hypotheses in two ways. First, area modelling was employed by overlaying maps of population density, previous population density, soil type and soil texture. The resulting unique conditions were analysed with analysis of covariance, with the map intersection areas as weights. The second method relied on analysis of point data from the grasshopper survey database, using the same statistical model. The results of both analytical methods indicated that grasshopper abundance was related to soil type ($P < 0.001$), but not to soil texture ($P > 0.1$), and the intrinsic hypothesis was rejected.

THE PHENOLOGY AND DYNAMICS OF A PERIODICAL CICADA EMERGENCE: A CORNUCOPIA? K.S. Williams*, K.G. Smith, Department of Zoology, and F.M. Stephen, Department of Entomology, University of Arkansas, Fayetteville, Arkansas USA 72701.

The synchronized emergence of periodical cicadas represents a pulse of perhaps the greatest biomass of herbivores per unit area known. All three species of the 13-year periodical cicada, Magicicada tredecassini, M. tredecim, and M. tredecula, emerged in Northwest Arkansas in 1985. This report describes the phenology of cicada emergence and distribution at one study site in Arkansas. Over 1 million cicadas emerged in 16 hectares, and approximately half of the population emerged within one week. We also discuss the effects of mortality factors on cicada population dynamics, such as catastrophic weather, short-term predator responses, and the fungal pathogen of periodical cicadas.

THE EFFECT OF HOST-FEEDING ON THE POPULATION DYNAMICS OF THE GREENHOUSE WHITEFLY (TRIALEURODES VAPORARIORUM WESTWOOD) AND THE PARASITOID ENCARSIA FORMOSA GAHAN. E. Yano*(1), N. Yamamura(2), (1)National Institute of Agro-Environmental Sciences, Tsukuba, Japan 305, (2)Saga Medical School, Nabeshima, Saga, Japan 840-01.

The aphelinid parasitoid Encarsia formosa Gahan is known to show host-feeding behaviour when it is exposed to larvae of the greenhouse whitefly. The effect of host-feeding on the population dynamics of the whitefly-parasitoid system was investigated using a simulation model and a simple mathematical model. In the simulation model, the population growth of whiteflies was described using a modified Leslie matrix model and the functional response of E. formosa to whiteflies was described as Holling's type II response. The dynamics of the system is supposed to be stabilized and the population level is suppressed by the effect of host-feeding. A Lotka-Volterra type model was constructed for the further investigation of the effect of host-feeding. Moderate effects of host-feeding give the minimum host density and the minimum fluctuation of the interactive system. Both models gave similar results concerning the effects of host-feeding on the dynamics of the host-parasitoid system.

RELATIVE IMPORTANCE OF PARASITIDS AND
PREDATORS IN THE DYNAMICS OF LOW DENSITY
GYPSY MOTH POPULATIONS. J.S. Elkinton*, A.M.
Liebhold, and J.R. Gould, Department of
Entomology, University of Massachusetts,
Amherst, MA 01003.

We have quantified gypsy moth survival,
mortality from disease and parasitism and
predation from birds and small mammals in
naturally occurring and artificially created
populations in Massachusetts. Our results
indicate that parasitism is strongly density
dependent under certain conditions and it is
probably more important to the overall
dynamics than previously thought. Predation
by small mammals is also important but we
find no evidence that it is positively
density dependent. Avian predation and
disease play minor roles in low density
dynamics.

FOOD-ENERGY-BUDGET AND SECONDARY PRODUCTIVITY OF
A NOCTOID LARVA PLUSIA ORICHALCEA FABR.
(LEPIDOPTERA).

S.C. Goel* and Vineet Kumar,
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Muzaffarnagar-251001, India.

In 37.79 days, the five instar caterpillars in the biology of P. orichalcea Fabr. assimilate 46.64% cal per individual of sunflower leaves and defecate 55.65% of the total ingestion. The net productivity in calories observed was 14.02% while 33.61% utilized in metabolic activities of the ingested food. Thus an unit mg of biomass provides enhanced body weight by 2.21 cal. The phased analysis for early instars had been 10.29% more of the tissue growth than the second phase of latter instars which demarcates the two characterized phases in the nutritional profile of caterpillars. The instarwise trend in caloric values has been successively increasing upto III instar whereas with an inverse pattern in the IV and V instars. The female pupa with 6.59 cal lower than the male gives out an adult female with 6.58 cal heavier for ovipositional activities.

THE NUTRITIONAL ECOLOGY AND MECHANISMS OF DIGESTION OF
C3 AND C4 GRASS-FEEDING LEPIDOPTERA. R.V. Barbehenn.
Department of Entomology, University of California,
Berkeley, CA, 94720.

The thick-walled bundle sheath cells of grasses with the C4 photosynthetic pathway are generally believed to cause these taxa to be difficult to digest. To test this hypothesis, growth, consumption, and nutritional indices of a lepidopteran larva (Paratrytone melane; HesperIIDae) were compared on both C3 and C4 grasses. The efficiency of digestion of protein and soluble carbohydrates was also measured. These data, along with a transmission electron microscopic examination of C4 grass fragments taken from larval guts, suggest that digestion may not be limited by an insect's inability to crush bundle sheath cells. Rather, growth on C4 grasses appears to be limited by the lower nutrient concentrations found in these plants.

BIOLOGY AND FEEDING OF THE LEAFHOPPER (EMPOASCA SOLANI (CURTIS)) (HOMOPTERA:AUCHENORRHYNCHA) ON VARIOUS SYNTHETIC DIETS. A. Wais, Institut of Plant Pathology & Plant Protection of the Georg-August-University Göttingen, FRG.

The leafhopper, Empoasca solani (Curtis), occurs only in the warm summer months in potato fields with high population densities in West Germany. It appears that the leafhopper may be a potential vector of the potato Y-virus. Adult insects preferred potato plants over sugar beet in free-choice bioassays. Laboratory tests comprising various synthetic diets were carried out at 20°C to study the biology and nutrition of the leafhopper. Oviposition could be obtained on some of the tested diets. Significant differences between the different food sources were found in the mean preoviposition time, adult longevity and fecundity of the adult insects. Of the tested diets a 1:9 dilution of the diet for the green peach aphid was proved to be the most suitable one for the nutrition of E. solani. On this diet, the leafhoppers could be maintained for a whole generation: the development time of the larvae was on the average 37.4 days and the longevity was 28.9 days compared to 30.4 days and 59.6 days on potato, respectively. Postembryonal development time could be determined as 3.6 days, if the eggs were isolated from the diets and incubated at 20°C in moist chambers containing potato leaves.

IS COTESIA CONGREGATA (SAY) (HYMENOPTERA: BRACONIDAE) BEHAVIORALLY ADAPTED TO THE FOODPLANTS OF ITS HOSTS? K.M. Kester* and P. Barbosa, Department of Entomology, University of Maryland, College Park, MD 20742 USA

Adaptations of parasitoids to the foodplants of their hosts are likely since parasitoids use plant chemicals in host-habitat or host location and their development or fitness may be affected by plant chemicals in their host's diet. If parasitoids are behaviorally adapted to the foodplants of their hosts then parasitoid populations may vary in their ability to locate hosts on different plants and may be deleteriously affected by herbivore hostshifts. We tested the preference of two geographically distinct populations of C. congregata, which also differed with respect to the common foodplant of their most common hosts, Manduca sexta (L.) and M. quinquemaculata (Haw.) (Lepidoptera: Sphingidae), to these hosts on a common vs. novel foodplant (tobacco or tomato) in the field. Both populations preferred to oviposit in hosts on the novel foodplant. Related wind-tunnel studies indicate that this parasitoid, which locates its hosts via plant damage, is behaviorally very flexible in its response to plants. Naive females often prefer to land at damage sites on nonhost plants over host foodplants and will not land on some common foodplants. We conclude that inherent searching preferences for common host foodplants are unlikely in this species.

PENTADECANAL - A SEMIOCHEMICAL FROM RICE. G.S.Ohalilwal and M.D. Pathak*, International Rice Research Institute, P.O.Box 933, Manila, Philippines.

Pentadecanal, a semiochemical isolated from a stemborer - resistant rice variety IKM 6, was found to possess wide range of toxic and morphogenetic effects against several species of insect pests, viz. Chilo suppressalis, Nilaparvata lugens, Scotatella furcifera, Ostrinia furnacalis and Heliothis armigera. The chemical exhibited strong oviposition deterrent and antifeedant properties against C. suppressalis. However, it was safe to two major predators of rice insects, viz. Cyrtorhinus lividipennis and Lycosa pseudoannulata. The implications of employing semiochemicals in pest management programmes are discussed.

CHEMICAL ECOLOGY AT THE THRESHOLD TO ADULTHOOD: H.E.Hummel, Institute of Phytopathology and Applied Zoology, Department of Biological and Biotechnical Plant Protection, Justus-Liebig-University, Ludwigstrasse 21, D-6300 Giessen, German Federal Republic.

Concurrently with the refinements achieved within the last three decades in chromatographic and spectrometric techniques, chemical ecology gradually gained, and can now claim, the status of an advanced branch of the life sciences, with notable accomplishments in the discipline of entomology.

Its students and practitioners recruit themselves from the fields of biochemistry, general- and micro-biology, analytical and synthetic chemistry, ecology, entomology, behavioral physiology, psychology, and toxicology. They are most successful when presented with the opportunity of an interdisciplinary approach.

Examples for current growing points and future needs of chemical ecology are being presented, including remarks on viable teaching programs and opportunities for professional advancement, specialized data banks, increased emphasis on plant-insect relationships, and biotechnical applications.

INITIATION, DEVELOPMENT AND TERMINATION OF PUPAL DIAPAUSE IN THE FALL WEBWORM, *HYPHANTRIA CUNEA* DRURY (ARCTIIDAE: LEPIDOPTERA). K.S. Boo*, M.Y. Choi and N.J. Park, Dept. Agric. Biol., Coll. Agric., Seoul Natl. Univ., Korea.

The fall webworm has two generations a year and overwinters as a diapausing pupae in Korea. In a laboratory test the threshold photoperiod for diapause was 14 hours and 15 or 25 min. at 25°C, depending on the generation. The short photoperiod must be experienced during about 10 days, from 5th to 15th day of larval development for diapause induction.

When taken out of the outdoors before Dec. 21, diapausing pupae never showed adult development. But taken to an insectary with the long photoperiod and 25°C on that date it took about 60 days for adult emergence. The period gradually decreased with time to become the same as that for normal (non-diapause) adult development at 25°C in early May. However, diapause-bound pupae of about 2 weeks old started a normal development and adult emerged when treated with 20-hydroxyecdysone.

Higher osmotic pressure in the hemolymph of diapausing pupae is closely related to higher content of trehalose and sorbitol. They also had more proteins but showed very low oxygen consumption rate, being only about 25% of the minimum level and about 9% of the maximum level observed during normal adult development.

ASPECTS OF THE PHOTOPERIODIC AND THERMOPERIODIC INDUCTION OF DIAPAUSE IN THE PHYTOSEIID MITE *AMBLYSEIUS POTENTILLAE*. Yvonne M. van Houten, Laboratory of Experimental Entomology, University of Amsterdam, Kruislaan 302, 1098 SM Amsterdam, The Netherlands.

The induction of diapause was studied in the phytoseiid mite *A. potentillae* (Garman). It was shown that diapause can be induced by short-day photoperiods at constant temperatures as well as by thermoperiods in continuous darkness. The thermoperiodic response curve determined for *A. potentillae* appeared to be closely similar to the photoperiodic response curve.

Moreover in *A. potentillae* the presence of a photoperiodic counter and a thermoperiodic counter was demonstrated. These two counters proved to be able to sum up photoperiodic cycles and thermoperiodic cycles respectively to a point at which diapause or non-diapause was induced. Indeed incidence of diapause was found to be dependent on the cumulative effects of both short-day photoperiods and diapause promoting thermoperiods.

SYNCHRONIZED, MASS-EMERGENCES OF A YUCCA MOTH, *PRODOXUS Y-INVERSUS*, AFTER 16 AND 17 YEARS IN DIAPAUSE.

J. A. Powell, Department of Entomological Sciences, University of California, Berkeley, CA, USA, 94720

Prolonged diapause, dormancy for more than one year, occurs in various insects and may have appreciable adaptive value, particularly in habitats characterized by erratic seasonal occurrence of the resources. Examples include several genera of prodoxine moths (Lepidoptera: Prodoxidae), which are dependent upon the brief annual flowering of yuccas and agaves (Agavaceae). In prior studies, adults of *Prodoxus* have metamorphosed after spending 4-8 years as prepupal larvae; this is a time span similar to the maximum survival in diapause reported for other insects.

During 14- and 16-day periods in 1985 and 1986, 120 and 61 adults of *P. y-inversus* eclosed from cocoons of the 1969 generation, collected in Nevada from *Yucca baccata* in April 1970. This suggests a potential for dormancy of much longer duration in phytophagous insects than previously supposed. The delayed emergence may have occurred because a series of suboptimal winters conditioned carryover larvae to develop more readily in circumstances that would not have been effective in an early year. The larvae may undergo some diapause development one year and continue it in another.

CURVILINEAR RESPONSE OF THE DEVELOPMENTAL RATES OF APHID CLONES AT LOW TEMPERATURES AND ESTIMATION OF A DEVELOPMENTAL THRESHOLD. R.J. Lamb, Agriculture Canada Research Station, 195 Dafoe Rd, Winnipeg, Manitoba, Canada R3T 2M9.

A linear relationship between developmental rate and rearing temperature is often used to estimate the developmental threshold and degree day requirements of insects, although the relationship is usually non-linear at temperatures near the threshold. The apparent non-linearity has been hypothesized to result because of genetic variation in developmental thresholds among insects. This hypothesis was tested for two clones of the pea aphid, *Acyrtosiphon pisum* (Harris). Individuals from a clone are genetically uniform and therefore, show no genetic variation in their developmental thresholds. Insects of both clones were reared at a series of constant temperatures starting near the developmental threshold, and their developmental times were measured. For both clones, the response of developmental rate to temperature was non-linear at temperatures near the developmental threshold, supporting the hypothesis that the non-linearity of the relationship is an intrinsic property of the developmental response to temperature. Based on this result, a method is proposed for estimating a developmental threshold from a non-linear relationship between developmental rate and temperature.

EMERGENCE PATTERN OF SCARABAEID BEETLES AND ITS RELATIONSHIP WITH METEOROLOGICAL FACTORS. Paras Nath* and J. Singh, Department of Entomology, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi-221005, Uttar Pradesh, India.

The ecological observations made on the scarabaeid insects revealed that the adult beetles are formed in the later part of March but remain inside the earthen cell until the first monsoon rain is received during June. The light trap study showed irregular emergence pattern of beetles. The combined and individual effects of rainfall, temperature, relative humidity and sunshine hours on the beetle emergence were of significant importance. The rainfall and relative humidity play major role on the emergence pattern of these insects. The relative abundance and frequency of emergence of 27 common species of lamelli-corn leaf-chafer and scavenger beetles on light trap are recorded and discussed in relation to some ecological parameters.

FORECASTING OF *LOBESIA BOTRANA* SCHIFF (LEPIDOPTERA: TORTRICIDAE) DEVELOPMENT BY WARMTH CONTENT IN THE AIR. E.D. Ashidze, Plant Protection Institute, Tbilisi, USSR.

The optimization of phytosanitary situation and data of protective measures in agroecosis are founded on reliable forecasting of pest and disease development. The sum of effective temperature doesn't always allow to judge about warmth quantity getting by organisms. The rate of insect development is not direct function of the air temperature. It is a certain complex function of many variable quantity forming thermal complex of atmosphere (temperature, humidity, content of warmth and moisture). The content of warmth and moisture was calculated by using Ramzin nomogram. As a result of our investigations average showing of warmth quantity required for *Lobesia botrana* larvae appearance in Georgia have been established. The estimating of forecasting method by air warmth content proved to be correct. This forecasting method can be used for time control signalization.

MECHANISM AND CHEMICAL ECOLOGY OF PEST RESISTANCE IN GERANIUMS (PELARGONIUM XHORTORUM). D.S. Walters*, R. Craig, and R.O. Mumma, Pesticide Research Lab., Department of Entomology, Pennsylvania State University, University Park, PA 16802, USA.

Garden variety geraniums exhibit resistance to most potential insect pests. However, some inbred geranium lines are susceptible to attack by the two-spotted spider mite (Tetranychus urticae Koch) and the foxglove aphid (Acyrtosiphon solani Harris) among other arthropod pests. Using comparisons between resistant and susceptible plant lines, the mechanism of pest resistance has been investigated and shown to be dependent upon a sticky glandular trichome exudate composed of anacardic acids. The biosynthetic pathway of these materials has been investigated using radiolabelled precursors and shown to be acetate-based. The inheritance of the resistance mechanism has been investigated in numerous crosses between resistant and susceptible lines. The integration of many separate avenues of research has enabled us to develop an understanding of the pest resistance mechanism at a fundamental level.

AMBIGUOUS ACTION OF THE ALLELOCHEMICAL VOLATILES OF PLANTS ON THEIR SATELLITE INSECTS. E. Thibout*, C. Lecomte and J. Auger, I.B.E.A.S., Faculté des Sciences, Parc Grandmont, 37200 TOURS, FRANCE.

The Sulphur allelochemicals of Allium and Cruciferae plants have an ambiguous role in relations with insects. These volatiles have a positive role for the plants because they defend them directly against phytophages not specialist of sulphur plants and indirectly against their specialists, Acrolepiopsis assectella and Plutella xylostella, in favorising their parasite wasp, Diadromus pulchellus. But they have also a negative role for the plants by stimulating diverse behaviours of their specialists.

Sulphur volatiles are sequestered in different proportions in the phytophage frass and in the plants. Disulfides could have a more important action in Cruciferae-insects relations than expected.

PHYTOPHAGOUS INSECTS AND DEFENCE MECHANISMS OF FIVE PROTEACEAE SPECIES IN THE CAPE MACCHIA. J.H. Coetzee, Vegetable and Ornamental Plant Research Institute, Private Bag X293, Pretoria 0001. South Africa.

Cape macchia or fynbos is the smallest of the six mediterranean ecosystems of the world, but has the highest plant species diversity. The Proteaceae is one of the dominant plant families of Cape macchia. To gather information on insect plant interactions in this biome the arboreal insect fauna of five Proteaceae was regularly sampled over a period of one year. Attention was also given to the effect of phytophagous insects on their respective host plants and defence mechanisms of these plants. About 150 species of herbivorous insects and 80 insect species that visited the inflorescences were found to be associated with the five species. These effect their host plants in different ways: insects that visit the inflorescences play a role in pollination; the borers in the inflorescences, infructescences and stems effect their reproduction while the chewers and leaf miners remove between 2 and 22 per cent of the leaf area.

The success of the Proteaceae indicates the presence of well-developed defence mechanisms. The latter are to be expected since the plants grow in nutrient deficient soils and would protect themselves from losing large amounts of plant material. In trying to understand the defence systems in Proteaceae, leaf properties such as chemical composition (particularly phenols, cyanogenic glucosides and nitrogen), pubescence, toughness and sclerophyll content were investigated.

SEED PREDATORS AND POSSIBLE BENEFITS TO PLANT RECRUITMENT: TESTING THE HYPOTHESIS. G.J. Forrester, Department of Pure and Applied Biology, Imperial College at Silwood Park, Ascot, Berks, SL5 7PY, U.K.

The hypothesis that seed predators may benefit plant recruitment from seed is investigated by field experiments. Seeds may be rendered distasteful to vertebrate seed consumers, such as rabbits, mice and voles, by the presence of the invertebrate seed predator, its frass, or both, and as a consequence infested seeds may have a higher rate of survival than healthy seeds. Experimental evidence will be presented that shows that this effect may be taking place in the English Oak (Quercus robur) and weevils of the genus Curculio.

SEED PARASITES AS POLLINATORS: INTERACTIONS BETWEEN TROLLIUS EUROPAEUS (RANUNCULACEAE) AND CHIASTOCHETA (DIPTERA: ANTHOMYLIDAE). Olle Pellmyr, Ecology and Evolution Dept, State Univ. of New York, Stony Brook, NY 11794, USA.

Pollination by seed parasites is unusual, and previously studied cases involve plant species (figs, yuccas) that are pollinated mostly by one host-specific pollinator. Trollius europaeus (Ranunculaceae), however, is pollinated exclusively by four Chastocheta species (Diptera: Anthomyiidae) that mate in the flowers, eat pollen and nectar, and complete larval development in the seeds.

Seed initiation frequency followed closely a function where a fixed proportion of remaining non-fertilized ovules were fertilized per egg laid. Because larval consumption was fixed while seed initiation decreased per visit, the n th larva consumed more seeds than its mother pollinated. The point of equal cost-benefit (where net effect of oviposition switches from positive to negative) was found to be around 4-5 eggs; observed population means per flower varied between 2.3-7.25 during three years of study. The system is rather insensitive to variation in pollinator density, remaining mutualistic over a wide range. Small changes in pollinator efficacy, however, can tilt the equilibrium to a negative net effect for the plant.

BEETLE POLLINATION OF NATIVE AND EXOTIC ANNONAS IN FLORIDA. H. Nadel*, J. Pena, Tropical Research and Education Center, 18905 SW 280th St., Homestead, FL 33031, and D. Habeck, Department of Entomology and Nematology, University of Florida, Gainesville, FL 32611.

Exotic annonas often set fruit at commercially adequate rates, indicating that they form novel associations with their beetle pollinators in new habitats. In Florida, the exotic sugar apple (Annona squamosa) and atemoya (A. squamosa X A. cherimola) are pollinated by nitidulids. We determined whether these beetles form part of the pollinator fauna of Florida's only native annona, A. glabra, or whether their role as pollinators is new. This information helps to predict the potential of indigenous faunas to pollinate annonas introduced for commercial purposes.

HOST PLANT STRESS AND NATURAL ENEMIES INFLUENCE DISTRIBUTION OF A SCALE INSECT MORE THAN DEMIC ADAPTATION. L.M. Hanks* and R.F. Denno, Department of Entomology, University of Maryland, College Park, MD, USA.

White peach scale, *Pseudalacaspis pentagona* Targ. (Homoptera: Diaspididae), is patchily distributed on its host trees to the extent that heavily infested trees may neighbor other trees entirely free of scales. Demic adaptation, host plant stress and natural enemies were examined as factors contributing to the observed contagious distribution of scales. It was concluded that demic adaptation of scale populations to host tree phenotype was of minor significance in influencing scale distribution and abundance because scale performance in cages was only slightly better on the original host than on other trees. Scales performed poorly on very stressed trees in ornamental plantings and best on trees in natural, woodlot settings when predators were excluded with cages. However, predators normally devastated scale populations on woodlot trees. Consequently scale populations are relegated to moderately stressed trees in urban habitats where predators are rare.

THE INFLUENCE OF THE SOURCE AND INTENSITY OF PLANT STRESS ON FECUNDITY OF THE TWO-SPOTTED SPIDER MITE, *TETRANYCHUS URTICAE*. G. M. English-Loeb, Department of Entomology, University of California at Davis, Davis, CA 95616.

I tested the hypothesis that plant stress, regardless of source, promotes arthropod outbreaks by measuring the fecundity of spider mites (*Tetranychus urticae*) on bush beans which were subjected to either drought stress, nitrogen deficiency, or mite feeding damage. While fecundity declined at slight drought stress, it increased again at moderate to severe stress. The opposite pattern was observed for nitrogen deficiency. Fecundity was unrelated to amount of feeding damage. These results show that the source, as well as intensity, of stress are important in determining spider mite response and suggest that broad generalizations about the role of plant stress in promoting pest outbreaks need to be refined.

THE IMPORTANCE OF PLANT SEX, GENOTYPE AND ENVIRONMENT IN RESISTANCE TO A SPECIALIST CHRYSOMELID HERBIVORE. Sharon Y. Strauss, Department of Biological Science, Florida State University, Tallahassee, FL 32306-2043.

Smooth sumac, *Rhus glabra*, is attacked by a variety of herbivores in central MN, but suffers the greatest reduction in fitness as a result of damage by a specialist chrysomelid beetle, *Blepharida rhois*. In spring 1986, two common gardens were established to examine the role of plant genotype, sex and environment in resistance to beetle attack. Twelve equal-aged ramets from 8 clones (5 female and 3 male) were dug up and planted in a completely randomized design in the gardens; each garden received 6 randomly-selected ramets from each clone (total: 48 ramets per garden). The gardens were allowed to rest for one year prior to experimentation. In spring 1987, gravid *B. rhois* females were collected from the field and eggs and larvae were reared from each female. Equal numbers of first-instar larvae of known parentage were placed on all ramets in both gardens. Larval survivorship was recorded and the experiment terminated as soon as one ramet had no remaining larvae. Analysis of variance was used to determine the contribution of each factor to larval survivorship.

THE INFLUENCE OF PLANT GENOTYPE AND ENVIRONMENT ON GALL MORPHOLOGY AND SURVIVORSHIP IN *PHYLLOCOLPA* SP. (HYMENOPTERA: TENTHREDINIDAE). R.L. Woodman* and P.W. Price, Dept. Biology, Northern Arizona University, Flagstaff, AZ, 86011 USA.

Leaf-folder galls on Arroyo Willow (*Salix lasiolepis*) were sampled in 8 sites in Arizona during summer, 1987. Relative gall morph frequencies, predation and parasitism levels, and gall density all varied among sites. Relative frequency of abnormal morphs is density-independent, but positively correlates with predation and parasitism levels. Variation in morph frequency between groups of plants and genotypes (sites) indicates environmental influences on gall morphology. Variation within sites suggests a plant genotype influence. Censuses of morph frequencies on willows of 6 genotypes (2 or 3 reps each) growing in a common garden indicate that genotype does influence the morphology. Both environment and genotype influence plant phenology, and insect phenology reflects environmental conditions. Both host plant genotype and environment may directly effect gall-maker survivorship through altering gall morphology and frequency, and thus consequent vulnerability to predators and parasitoids. A model is proposed where plant genotype and environment influence plant and sawfly phenology, and when these are mismatched, gall morph frequency and survivorship are changed.

TOWERING TREES, DIMINUTIVE SCALES: WHO SUBDUED THE LOVELY LIGNUM VITAE?. L.J. Mason*, R.M. Baranowski and P. Veno, Tropical Research and Education Center, University of Florida, 18905 S.W. 280 St., Homestead, FL, 33031.

Lignumvitae Key State Botanical Site is one of the few remaining protected sites for lignum vitae (*Guaiacum sanctum* Linn.). Recently, the population of lignum vitae within the preserve has declined and shows signs of severe defoliation. It has been speculated that this decline may be due to an undescribed species of *Toumeyella* scale or to extensive shading of the trees. Aspects of the scale's biology, its interaction with lignum vitae, and the influence of shading on laboratory and natural populations were studied. Evidence suggests that shading is responsible for the decline.

MOVEMENTS OF CARABID BEETLES (COLEOPTERA: CARABIDAE) IN DIFFERENT HABITATS: RESULTS FROM FIELD TRACING EXPERIMENTS. H. Wallin¹, B.S. Eklom¹, P. Hockmann, P. Schlöner and F. Weber, ¹Swedish University of Agricultural Sciences, Department of Plant and Forest Protection, P.O. Box 7044, S-750 07 Uppsala, Sweden; Zoologisches Institut der Universität, Schlossplatz 5, D-4400 Münster, FRG.

The individual movements of five nocturnal carabid species were investigated using a portable radar system (harmonic radar). The field-/forest-inhabiting *Pterostichus melanarius* Illiger and *P. niger* Schaller displayed directed movements in arable fields. In a forest, *P. melanarius* showed mainly random movements (a correlated random walk), similar to those obtained for the forest-species *Carabus nemoralis* Miller. *P. niger* exhibited directed movements in a forest, and showed the most rapid movements of all species studied. The strictly field-inhabiting *Harpalus rufipes* De Geer showed random movements in arable fields. Burrowing was found to be a typical behavior among all field-inhabiting species. Hunger had little effect on movement patterns, although hungry *P. niger* tended to change directions more frequently than did satiated ones. The forest-species *C. auronitens* F. was found to expend a large proportion of its activity climbing and foraging on trees. Males of both *C. nemoralis* and *C. auronitens* moved significantly faster than females. However, both sexes were able to maintain a certain compass direction for several nights during the first weeks of their reproductive periods. The significance of the various movement patterns exhibited by the species studied for their reproduction and survival is discussed.

ORIENTATION AND DISPERSION OF *ANASTREPHA LUDENS* (LOEW) (DIPTERA TEPHRITIDAE) IN THE ALLENDE, N.L. MEXICO AREA. Walther R. Enkerlin* and Dieter Enkerlin, Programa Mosca Med, SARH and Inst. Tech. Monterrey, Mexico.

During 1985-86, supported by USDA/APHIS/PPQ/LAR, the orientation and/or movement of *A. ludens* was studied in the Allende, N.L. area where citrus is grown for the export and local market. In all of the citrus areas of the State, fly-free zones must be established for exporting fruit without fumigation. This approach must include releases of sterile *A. ludens* flies. Therefore the movement of sterile released adults was studied, by making weekly releases of color marked flies in two areas: the first on a hill mostly with brush, some sour citrus and *Diospyros texana* as well as *D. palmieri* as potential hosts; and the second in an area with "yellow chapote" *Sargentia greggii* and small family orchards around. McPhail traps baited with Torula yeast were used for monitoring sterile and wild populations. Results indicate that winds definitely influence dispersion of released flies but maturing fruits in host orchards also have a definite influence. The tendency of dispersion towards the northeast and northwest was proven under field conditions. Wild *A. ludens*, *A. serpentina*, *A. fraterculus* and others were also captured.

INVESTIGATIONS OF FLIGHT AND REPRODUCTIVE ABILITIES OF THE LIGHT BROWN APPLE MOTH, *EPIPHAS POSTVITTANA* (TORTRICIDAE). W. Dathanarayana and H. Gu, Department of Zoology, The University of New England, Armidale, NSW, 2351, Australia.

E. postvittana is a nocturnal flyer showing a lunar periodicity of flight activity. The mean longevity of the adult is 17 days, during which about 307 eggs are laid on the average. Egg laying occurs within 24 hours after emergence with 27% laid by day 3, 50% by day 6 and 83% by day 8. Flight ability, measured by a tethered technique, was highest in 4-7 day old mated females and 4-8 day old unmated males. The proportion of moths exhibiting the longest bouts of flight was greatest among the 5-7 day old mated females whereas females aged less than 3 days or more than 10 days did not show prolonged flights. Thus lengthy bouts of flights occur after the moths have laid about 30% of their eggs. This simultaneous maximization of both flight and reproductive parameters should find its value in the colonization capability of this species. Preliminary observations within an activity meter show that the greatest amount of restlessness occurs during the full moon period. Implications of these findings will be discussed.

GENETICS OF FLIGHT POTENTIAL IN A MIGRANT MOTH, THE AFRICAN ARMYWORM, *SPODOPTERA EXEMPTA* (WALK.) (LEPIDOPTERA: NOCTUIDAE). A.G. Gatehouse* and K.P. Woodrow, School of Animal Biology, University College of North Wales, Bangor, Gwynedd LL57 2UW, U.K.

Evidence from experiments in which the times and durations of flights by tethered moths were recorded in the laboratory, strongly suggests that migratory flight capacity in *S. exempta* is determined genetically and modulated by larval density. There was a rapid response to selection for long and short flight and heritabilities for flight duration were consistently higher when only flights starting at times of night when radar shows migratory flights to commence in the field, were included in the analysis.

In lines selected for increased flight potential, a bimodal distribution of flight durations was evident in the F1 generations but not subsequently, indicating the involvement of a major gene. A model is proposed to explain these data and is discussed in relation to the migratory strategy of the African armyworm.

MIGRATION AND DISPERSAL IN PENTATOMOIDEA (HEMIPTERA: HETEROPTERA). M. Javahery, Department of Entomology and Lyman Entomological Museum, Macdonald College of McGill Univ., Ste. Anne de Bellevue, Québec, Canada H9X 1C0.

The movement behaviour and seasonal displacement of 28 phytophagous bugs were observed in habitats of various ecological and climatological conditions. Simultaneously, the reproductive activities and seasonal changes in population of these insects were closely investigated. Among the species studied some are almost or entirely non-migratory (e.g. *Aelia acuminata* L.) while the majority are semi-migratory (e.g. *Acrosternum hilare* (Say)); certain species, such as *Eurygaster integriceps* Puton are strongly migratory.

These insects migrate in summer to their aestivation sites (either at high altitudes in the mountains or at lower altitudes on the trees). Subsequently, they hibernate either under bushes at high altitudes or within leaf litter in the woodlands. The overwintered bugs return again in the spring to their preferred plants where they feed and breed. All species studied are univoltine. Migration or displacement of these bugs occurs during the pre-reproduction period. These movements are obligatory and is an evolutionary adaptation which ensure their survival.

REGIONAL ADAPTATIONS IN THE PHENOLOGY OF A MIGRANT APHID, *RHOPALOSIPHUM PADI* (HOMOPTERA: APHIDIDAE). G.M. Tatchell, The A.F.R.C. Institute of Arable Crops Research, Rothamsted Experimental Station, Harpenden, Herts., AL5 2JQ, England.

Analysis of 17 years data from the Rothamsted Insect Survey network of suction traps throughout Britain reveals regional adaptations in the phenology of the bird cherry aphid (*Rhopalosiphum padi*). This aphid is mainly holocyclic in Britain, with three periods of redistribution during the year. In spring emigrants leave the primary host (*Prunus padus*) in search of Gramineae; in summer alate exules redistribute between Gramineae; in autumn gynoparae and males return to *P. padus*. In some areas a proportion of *R. padi* are anholocyclic remaining on Gramineae all year.

Six phenological events were examined: 1 first migrant; 2 peak spring migration; 3 peak summer migration; 4 peak female migration in autumn; 5 first male; 6 peak male migration. First migrant and peak summer migration were earlier in the warmer south. Peak spring migration of anholocyclic populations in the south was a week earlier than holocyclic ones in the north. In autumn the peak of male and female migration was similar at all latitudes. First males occurred earlier in the north than south which, considering the daylengths, can only be explained by regional adaptations anticipating the onset of winter. The stable phenological patterns suggest that migration caused limited mixing of aphid populations.

WHEN IS SUPERPARASITISM ADAPTIVE FOR SOLITARY PARASITOIDS? M.E. Visser¹, J.J.M. van Alphen¹, F.H.D. van Batenburg² & Y.M. Fisser², ¹Department of Population Biology, ²Institute for Theoretical Biology, Leiden University, P.O. Box 9516, 2300 RA Leiden, the Netherlands.

Intraspecific host discrimination has been shown for many parasitoid species. Yet, often superparasitism is found. The functional significance of this behaviour for gregarious parasitoids can easily be understood, but for solitary parasitoids this is less obvious.

Both a deterministic and a stochastic model have been developed in order to investigate under which circumstances it is advantageous for a solitary parasitoid to superparasitize. The models show that variables as handling time, number of searching females and encounter rate determine when a female should start to superparasitize. Predictions were tested qualitatively by a literature study and quantitatively by experiments with the *Drosophila*-parasitoid *Leptopilina clavipes* (Hymenoptera: Eucolidae).

ADAPTIVE PLASTICITY OF THE LARVAL PERIOD. Martin Taylor, Department of Biology, Princeton University, Princeton, NJ 08544, USA.

The duration of the larval stage has important fitness consequences. Extended larval period has the advantage of more time for feeding, and thus greater adult size and increased fecundity. The disadvantages are increased risk of death before reproduction, and the competitive loss of delayed reproduction. The larval periods of many insects show great variability as growth rates change with temperature and nutrition. Does this variation represent active optimisation of duration of larval period, or is larval period the passive outcome of fixed rules of development?

Results of a study of environment-related variation in the life history of the moth *Samea multiplicalis*, support the adaptive hypothesis. Variance of larval period was much greater than for egg and pupal periods, and accounted for most of the variance in generation time. A lack of fixed rules was attested by the variability of instar number and adult size. Development data were not explained by an appropriate fixed-rule model. However, experiments have yet to be done which conclusively demonstrate a proximate mechanism of adaptive control of duration of the larval period.

EVOLUTIONARY INSTABILITY OF COMPLEX LIFE CYCLES IN APHIDS. C.D. von Dohlen* and D.E. Gill, Department of Zoology, University of Maryland, College Park, Maryland 20742 USA.

A second, monoecious life cycle has been documented in the witch-hazel leaf gall aphid, *Hormaphis hamamelidis*, in eastern North America. Confirmed by our studies in lowland elevations and latitudes, the original published account described a host-alternating life cycle between witch-hazel (1° host) and river birch (2° host). In contrast, at higher elevations and latitudes we found populations with an abbreviated cycle on witch-hazel only.

Within the 2 genera of the tribe Hormaphidini, 5 other species are reported to be either anholocyclic on birch, or heteroecious between witch-hazel and birch. Thus the new life cycle is the only one known to be monoecious on the 1° host; it is a new species.

Although the general aphid literature presumes that a monoecious cycle on the 1° host is ancestral to a complex heteroecious one, the application of complex life cycle evolution theory suggests an alternative hypothesis: the monoecious cycle is secondarily derived from an evolutionarily unstable complex one. The life cycles and geographic ranges of species related to *H. hamamelidis* suggest a phylogeny to support the latter hypothesis.

HOW PLANTS OBTAIN PREDATORY MITES AS BODY GUARDS. M. Dicke* and M.W. Sabelis

Host plants affect phytophagous mites, predatory mites and their interactions in various ways. In absence of phytophagous mites, plants may provide alternative food sources such as pollen or plant exudates to the predatory mites. In this way the plant ensures itself of body guards before any herbivore damage has been inflicted. When attack by phytophagous mites is expected to occur very soon, or has already taken place, plants lacking (sufficient) body guards may do better by luring predatory mites. Current evidence suggests that plants infested by spider mites start producing volatile chemicals and that these products convey information to predatory mites that search for prey.

At the other extreme, there are plants that invest extensively in a more direct defence against herbivores, even if this is to the detriment of the predators.

Examples of these various plant predator interactions will be given and their evolutionary implications will be discussed.

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ADAPTATIONS IN TROGID CARRION BEETLES (COLEOPTERA: TROGIDAE) TO EXTREMELY ARID CONDITIONS. C.H. Scholtz*, Department of Entomology, University of Pretoria, 0002, South Africa, and S. Caveney, Department of Zoology, University of Western Ontario, London N6A 5B7, Canada.

Trogid species of the genus *Omorgus* in the arid Kalahari are morphologically, behaviourally and physiologically adapted to survive extremely arid periods interspersed with short favourable periods during which feeding and breeding take place. The most important strategies for survival are: a biphasic daily activity pattern which coincides with peaks in relative humidity and the inverse in temperature; the ability of adults and larvae to enter a quiescent state under adverse environmental conditions, which can be terminated within hours of an improvement in conditions; rapid immature development, long adult life and consequent overlapping generations; suspended ovariole development; and a tendency to a flightless condition.

SEASONS IN PANAMANIAN CICADAS. RAIN OR DAYLENGTH (HOMOPTERA: CICADOIDEA). H. Wolda*, Smithsonian Tropical Research Institute, Balboa, Republic of Panama.

Eight of the eleven common cicadas on Barro Colorado Island, Panama occur at the beginning of the rainy season, the remaining three occurring in the dry season. On the average, six of the eight rainy season species begin to appear at the time the rainy season tends to start, one starting a few weeks earlier, and one a few weeks later. The actual start of the rains in any one year, however, has an only very low positive correlation with the appearance of the first individuals of any one species. Moreover, the first individuals often appear before the rains. Similarly, the correlations between the actual onset of the dry season and the appearance of the dry season species is low. The temporal strategies of these insects seem to be evolutionarily geared to the meteorological seasons, but rain or dry weather are not the seasonal cues triggering adult emergence. Daylength, through its effect on the plants, seems to provide a more likely trigger mechanism.

Some circumstantial evidence suggests that interference by sound may affect the seasonal pattern of two of these cicada species.

AN OUTBREAK OF *LOCUSTA MIGRATORIA* AND ITS CRUSH DUE TO *ENTOMOPHAGA GRYLLI* ON MAGESHIMA ISLAND, JAPAN IN 1986-1987. Akira Tanaka*, Kagoshima Agric. Expt. Stn., Kagoshima city, Japan 891-01 and Keizi Kiritani, Div. Ent., NIAES, Tsukuba city, Japan 305.

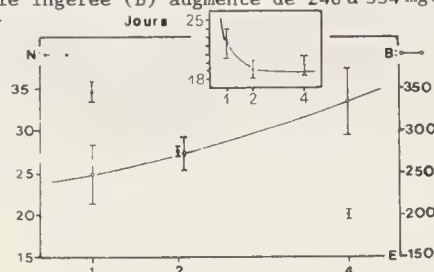
An outbreak of *Locusta migratoria* L. was observed in September 1986 on Mageshima Island (820ha, N30°45', E130°51'), 11km west of Tanegashima Island, Kagoshima Prefecture, Japan. The island was no inhabitants since 1980. Marching, basking and hopper bands of nymphs were observed from September to mid-October. Some 50 million adults were observed in a form of a swarm over the island, moving from one place to another by repeated feeding, flying and resting until the end of November. Gramineous plants on the island were almost entirely eaten by the locusts. In addition to the adult swarming, the darker body colour, higher in E/F and lower in F/C ratios and concaved pronotum of the adults indicated that they were in the gregarious phase. The adults overwintered in groups among the vegetation of grasses and died after laying egg masses in the following months of March to May. The eggs hatched in May to June, but the nymphs and adults were almost completely killed by the infection of *Entomophaga grylli* by June 1987 before the second generation.

PREDATION DE LA LARVE DE *TETANOCERA FERRUGINEA* (DIPTERA : SCIOMYZIDAE) EN FONCTION DU NOMBRE D'ESPÈCES DE MOLLUSQUES-PROIES. S. Manguin*, J.C. Vala, C. Gasc. Laboratoire de Biologie Animale, Faculté des Sciences, 33, rue L. Pasteur 84000 Avignon, France.

T. ferruginea est un Sciomyzide à larves aquatiques, prédatrices de mollusques dulçaquicoles.

L'augmentation du nombre d'espèces de mollusques-proies dans le milieu (1, 2 ou 4 espèces, sur un total fixe de 20 proies), engendre une triple influence sur la prédation de la larve. a) La durée du développement larvaire se réduit de 22 à 19 jours en moyenne (encart de la figure). b) Le nombre total de proies consommées (N) par la larve diminue de 35 à 20 proies, c) alors que la biomasse totale ingérée (B) augmente de 248 à 334 mg. Par conséquent, la larve de *T. ferruginea*

tend à consommer une biomasse élevée de proies pour un minimum de captures et exploite au mieux son environnement en effectuant un choix parmi les proies disponibles.



DENSITY-RELATED VARIATIONS IN LIFE-HISTORY PARAMETERS IN THE APHID PARASITE *APHELINUS ASYCHIS* WALKER (HYMENOPTERA: APHELINIDAE). B. Bai*, M. Mackauer, Department of Biological Sciences, Simon Fraser University, Burnaby, British Columbia, Canada V5A 1S6

Aphelinus females were provided in the laboratory with different numbers of pea aphids, *Acyrtosiphon pisum* Harris (Homoptera: Aphididae), for fixed periods of time. Females laid an average of one egg per day when provided with three second instar aphids; this number increased to nine at a host density of forty. The number of aphids parasitized and killed by host feeding increased with the number of aphids available. At low host densities (≤ 12 aphids/day), the proportion of aphids parasitized as well as the number of eggs laid per host available increased with host availability. These parameters declined at high host densities (≥ 15 aphids/day), a condition resulting in a dome-shaped density relationship. *Aphelinus* females superparasitized their hosts at all densities. The results are discussed with regard to ecological theories of density dependence and biological control.

AUGMENTATION OF GENERALIST APHID PREDATORS USING AN EXOTIC ALTERNATE HOST: THE PECAN-CRAPE MYRTLE APHID SYSTEM. R. Mizell*, D. Schiffhauer and P. Stiling, University of Florida, AREC-Monticello, Route 4 Box 63, Monticello, Florida 32344.

The predator complex of pecan aphids also feeds on the crapemyrtle aphid, an exotic, host specific species. We have shown that use of crape myrtle in pecan to augment predators such as coccinellids, chrysopids, mirids, anthocorids, etc. may greatly enhance biological control of pecan aphids. Some important aspects of the predator-prey relationships will be discussed.

HOST-FEEDING STRATEGIES IN PARASITOIDS - A TEST OF A MODEL. H.E. Almey*, M.A. Jervis and N.A.C. Kidd, Department of Zoology, University College, Cardiff, Wales, U.K. CF1 1XL.

As well as deciding which patches to visit, when to leave a patch, what clutch size to produce and what sex ratio to produce, a host feeding parasitoid also has to decide whether to feed and/or oviposit. When parasitoid-host population dynamics are considered it is a characteristic of behaviour that is often ignored. Analytical models are currently being developed to incorporate this aspect of behaviour.

Using *Bracon hebetor* (Say) (Hymenoptera: Braconidae) a gregarious parasitoid of Phycitid moths, the phenomenon of host feeding is examined under laboratory conditions. The importance of host stage and host abundance is explored with respect to feeding behaviour, fecundity and egg resorption in the adult female. The possible implications of host feeding on host-parasitoid interactions are then discussed with reference to analytical models.

AGGREGATIVE FORAGING BY FIELD POPULATIONS OF *EPIDINOCARSIS LOPEZI*, DE SANTIS (HYMENOPTERA: ENCYRTIDAE) A PARASITOID OF THE CASSAVA MEALYBUG, *PHENACOCCLUS MANIHOTI* MATILE-FERRERO (HOMOPTERA: PSEUDOCOCCIDAE).

W.N.O. Hammond*, International Institute of Tropical Agriculture (IITA) P.M.B. 5320 Ibadan, Nigeria; J.J.M. van Alphen, Division of Population Ecology, University of Leiden, Postbus 9516 Kaiserstraat 63, Leiden, Netherlands; and P. Neuenschwander, IITA.

Studies on the allocation of foraging time by field populations of *E. lopezi* on various densities of its host the cassava mealybug (CM) were conducted in February/March 1987 during the dry season, in order to explain the suppression of CM populations by this introduced parasitoid. The released *E. lopezi* concentrated on cassava tips artificially infested with 2, 4, 8, 16, 32, 64, and 128 CM per tip as compared to uninfested (control) tips. Individual wasps spent more time foraging on infested tips than on controls. There was significant aggregation of *E. lopezi* as measured by three methods (Power law, b; mean crowding index, B; and negative binomial, k). The number of parasitized hosts increased significantly with CM densities up to 64, but not sufficiently for a positive density dependent relationship. The implications of such aggregation behaviour by *E. lopezi* on the host-parasitoid system are discussed.

LABORATORY STUDIES ON THREE SPECIES OF LEAF-HOPPER EGG PARASITOIDS OF THE GENUS ANAGRUS (HYMENOPTERA: MYMARIDAE), Mario S. Moratorio

Anagrus mutans Walker, Anagrus silwoodensis Walker and Anagrus giraulti Crawford are leafhopper egg parasitoids. The first two species were collected and studied in Silwood Park, near Ascot, in Berkshire, England, while the latter, a parasitoid of the beet leafhopper, Circulifer tenellus (Baker), was collected and studied in California.

The field biologies of A. mutans and A. silwoodensis differ greatly from those of A. giraulti--the first two species overwinter as mature second instar larvae while the latter is found year round. When their biologies were studied in the laboratory, they were remarkably similar.

Here, several aspects of the laboratory studies of the three species will be presented and discussed. Laboratory studies were conducted on timing of emergence, copulation and oviposition behaviors, relationships between size and fertility, and larval development. The results of these studies are presented and discussed.

HOST PLANT SEGREGATION AMONG THREE PIERIS BUTTERFLIES IN RELATION TO THEIR DEFENSE AGAINST TWO COMMON PARASITOIDS. N.Ohsaki* and Y.Sato, Entomological Laboratory, College of Agriculture, Kyoto University, and Department of Zoology, Kyoto University, Kyoto, 606, Japan.

Three Pieris butterflies, P. rapae, P. melete and P. napi coexist in mountainous areas in Japan. The larvae of all the three species feed on cruciferous plants, although their host plants are different species. P. rapae mainly uses cultivated plants such as cabbage and radish. P. napi uses only Arabis plants. P. melete uses many crucifers (but not Arabis). We determined the nutritional suitability of the cruciferous plants for the three Pieris larvae by examining the larval growth rates in the laboratory. The cultivated crucifers are nutritionally the most suitable for all the three species. By contrast, Arabis plants are the least suitable, even for P. napi.

Why do P. melete in open areas and P. napi not use cultivated plants? Why in P. napi strongly restricted to Arabis plants even though Arabis plants are nutritionally the most unsuitable of all cruciferous plants for P. napi? What factors cause these three butterflies to use different sets of crucifer host plants? The differential use of crucifers by the three Pieris species may be caused by the differences in their defense mechanisms against two habitual parasitoids, a wasp Apanteles glomeratus and a fly Epicampocera succincta.

PATCH TIME ALLOCATION IN THE PARASITOID, OEOENCYRTUS NEZARAE, AS INFLUENCED BY FOOD SEEKING. K. Takasu* and Y. Hirose, Institute of Biological Control, Kyushu University, Fukuoka 812, Japan.

Adult females of parasitoids often take foods, such as honeydew and plant nectaries, for the egg maturation and sustaining life during foraging for the hosts. In foraging studies of these females, however, the effect of such feeding by the females on their foraging for the hosts has little been considered. We found that the food seeking by females of Ooencyrtus nezarae, a solitary egg parasitoid of the bug Megacopta punctissimum, has a great influence on their foraging for the host. This host bug lays its eggs in groups of 10-50. Both in the laboratory and in the field, on encountering the groups of 10 host eggs, most of the females each oviposited in all the host eggs in an egg mass. But, in groups of 20 or 40 host eggs, many of the females each left an egg mass before completing their oviposition in all the hosts in the egg mass. This was because each female left the host egg mass to seek for her food. It is concluded that females of O. nezarae are seriously affected in foraging efficiency by their food seeking.

OPTIMAL PATCH USE BY PARASITOIDS WITH LOW FECUNDITY.

Y. Yamada, Entomology Laboratory, Faculty of Bioresources, Mie University, Tsu 514, Japan.

A mathematical model is presented which predicts the expected optimal-patch-use strategy for solid parasitoids with low fecundity, strictly speaking, parasitoids which have so long egg-maturation time that the parasitoids lay a limited number of eggs per unit time however frequently they encounter hosts. The model predicts that throughout the searching period the parasitoids should maintain parasitism rate equal in all the patches irrespective of host density per patch.

The spatial pattern of parasitism among field patches by a parasitoid with a low fecundity, Praestochrysis shanghaiensis, shows fairly good agreement with the prediction of the model, a similar level of parasitism in different patches, when the whole ratio of parasitoid to host in all the patches is high. When it is low, however, the level of parasitism per patch shows an inverse density dependency, and is positively associated with the parasitoid-host ratio.

The model presented here assumes that the parasitoids move between patches without cost and have perfect information about patch quality. Consideration of cost for moving and sampling bridges the above gap between the observed and predicted spatial patterns of parasitism.

CAUSE OF A REFUGE FOR CALIFORNIA RED SCALE: TEST OF THE SIZE HYPOTHESIS. S.J. Walde, Department of Biological Sciences, University of California, Santa Barbara, CA, U.S.A. 93106

The woody bark of the interior branches of citrus trees has been shown to act as refuge area for California red scale from its controlling parasitoid wasp, Aphytis melinus. Individual scale in the refuge are, on average, smaller than scale on the exterior twigs and fruit. It was proposed that size-selectivity might account for the low parasitism rate in the refuge. Laboratory experiments confirmed that Aphytis does select larger hosts. However, the degree of selectivity exhibited by Aphytis can explain only a small portion of the difference in field parasitism rates, and thus alone cannot account for the presence of the refuge.

THE ROLE OF A NEWLY DESCRIBED MICROORGANISM IN THE LIFE CYCLE OF RHAGOLETIS POMONELLA. C.R. Lauzon, A.A. Rutkowski W.W. Currier and G.B. MacCollom*, Departments of Plant and Soil Science, Microbiology, and Agricultural Biochemistry, University of Vermont, Burlington, Vermont, 05405, U.S.A.

Symbiotic bacteria appear to be essential for survival for several Tephritids. Unfortunately, information regarding the relationship(s) between microorganisms and Tephritid flies remains unclear despite contributions by several investigators. Attempts have been made to define the symbiotic associations of microbes and the apple maggot, but questions remain.

Evidence suggests that a new member of the family Enterobacteriaceae is associated with the life cycle of Rhagoletis pomonella. Cultures were derived from female apple maggot flies, larvae, and from apple tissue surrounding oviposition sites, with all specimens gathered from experimental orchard sites. Standard biochemical testing reveals a species not yet described by any research to date. The Enterobacter sp. possesses the ability to rot apple tissue. Preliminary evidence suggests attractiveness to the organism by both male and female flies.

SOME ASPECTS OF THE ECOLOGY OF THE GRANIVOROUS ANT MESSOR CAPENSIS (MAYR) IN SEMI-ARID GRASSVELD. M.J. Vorster and P.H. Hewitt*, Department of Zoology and Entomology, University of the Orange Free State, Bloemfontein, 9300 RSA.

M. capensis workers were active from early spring (September) until early winter (June). They were inactive during July and August. Most of the successful foraging took place in late summer and early autumn and seeds of both grasses and perennial shrubs were collected. Apart from pioneer grass seeds which were collected in large numbers diversity was largely a reflection of botanical composition.

Plant material which is deposited outside the nest entrance was collected at regular intervals and analysed. It contained seed husks as well as unutilized seeds. Foraging distances, size of foraging areas, constancy of trails, size of seeds collected in relation to forager size as well as recruitment were studied.

Various factors which could affect the distribution of M. capensis nests were identified.

SOIL PROTURIAN COMMUNITIES IN FOREST OF TIANMU MOUNTAIN, EAST CHINA. W.Y. Yin and L. Zhao, Shanghai Institute of Entomology, Academia Sinica, Shanghai 200025, China.

From 1986-1987 an investigation on soil fauna in the Natural Preserve Area of Tianmu Mountain was conducted. Proturian communities of five stations were especially studied in detail at species level. There are totally 23 species belonging to six families of Protura. The largest species number (14) and the highest density $365/m^2$ were obtained from st.IV (600 m) in a deciduous and coniferous mixed forest, and in contrast to that a very few species adapted to rather poor Cryptomeria forest at st. V. The dominant group is Eosentomidae, consisting of 12 species, and the dominant individual is Neocondeellum dolichotarsum (Protentomidae), which seems existing only under 1,000 m height. Analysis of relative abundance in species and individual of the three major groups of Protura, i.e. the EBP-analysis revealed that on the top of the mountain, st.I (1500 m) is E-type, then change to EP-type and P-type in the lower most station V (400 m).

ENVIRONMENTAL PREDICTIONS AND DISTRIBUTIONAL LIMITS OF CHROMOSOMAL TAXA IN THE AUSTRALIAN GRASSHOPPER *CALEDIA CAPTIVA* (F.). B. Kohlmann, Pop. Gen. Group, R.S.B.S., A.N.U., P.O. Box 475, Canberra 2601, Australia and Institute of Ecology Mexico-City 11800, Mexico.

Correlations between environmental parameters and the distribution of four chromosomal taxa in the acridine grasshopper *Caledia captiva* (F.) have been analyzed. A bioclimate prediction system (BIOCLIM) was used as a model to determine bioclimatic envelopes and predict probable geographic distributions. A non-metric multi-dimensional scaling of a parapatric boundary confirms the nature of geographic correlation with different climatic extreme values.

One of the parapatric boundaries seems to be of recent origin (2,000-6,000 years) on the basis of the location of extreme climatic values as well as chromosomal and genetic markers and is expected to move further south and east of its present location. The analysis suggests that sharp parapatric distributions may be maintained by gradual environmental influences and coincidence with ecotones is not necessary.

FACTORS AFFECTING THE DISTRIBUTION OF SHORE BUGS (HEMIPTERA: SALDIDAE) IN THERMAL, SALINE SPRINGS. V.H. Resh, Department of Entomology, University of California, Berkeley, California 94720, USA.

Saldula usingeri Polhemus occurs in California coastal springs that have high concentrations of Na (4,600-10,000 ppm), Cl (8,050-12,100 ppm), and Li (6.5-12.5 ppm). *Saldula* spp. and *S. usingeri* coexist at lower concentrations of these elements (Na: 1,064-1,500 ppm; Cl: 1,150-2,410 ppm; Li: 1.7-4.8 ppm); below these concentrations *Saldula* spp. occur but *S. usingeri* is absent. In laboratory tests *S. usingeri* lives significantly longer than closely related *Saldula* spp. when cultured in its own highly saline habitat water; however, survivorship is similar in the low salinity water of *Saldula* spp.'s habitats. Tests with glycine-radiolabelled water indicate that *S. usingeri* imbibes water from its prey, larval brine flies, rather than imbibing its own habitat water. By imbibing fluids this way, *S. usingeri* expends less energy for osmoregulation and its intake of toxic ions is reduced. Susceptibility of *S. usingeri*, which are very slow moving compared to other *saldids*, to spider predation may explain its absence from habitats that it can tolerate. The sluggish behavior of *S. usingeri* may be an advantage when it occurs along the margins of lethal thermal effluents but it may be a disadvantage in habitats having mobile predators.

ZONATION OF CARABIDAE (COLEOPTERA) ON STONY LACUSTRINE BEACHES: PATTERN AND PROCESS. N.J. Holliday, Department of Entomology, University of Manitoba, Winnipeg, Manitoba, Canada R3T 2N2.

Four species of carabid beetles are common on stony beaches of the southern basin of Lake Winnipeg, Manitoba. They are *Chlaenius cordicollis* Kirby, *Bembidion concolor* Kirby, *B. scopulinum*, and *B. transversale* Dejean.

In summer, *B. transversale* occurred near the water's edge, and *B. concolor* was found near the top of the beach; *C. cordicollis* and *B. scopulinum* occupied intermediate positions. In artificial beaches, zonation of each species was not affected by the presence or absence of the other species. Exposing beetles to 100% relative humidity or to a relatively dry atmosphere showed that tolerance of dryness and high humidity of each species was concordant with that predicted from its zonation in summer.

In winter, *C. cordicollis* and *B. transversale* occurred in aggregations at the top of beaches; the winter habitat of the other species is unknown. Experiments on the cold-hardiness of *C. cordicollis* suggested that, in order to survive the winter, it requires the insulation provided by snow drifts that accumulate at the top of the beaches.

A MORPHOLOGICAL CLINE: ADAPTATION TO CLIMATE OR RESULT OF GENE EXCHANGE BY HYBRIDISATION - WHAT LIMITS THE TERRITORY OF *CARABUS LINEATUS* (COLEOPTERA: CARABIDAE)? A. Roschen, Universität Bremen - NW II Evolutionsbiologie, Leobener Str., D-2800 Bremen 33.

The area of *C. lineatus* Dejean reaches from north-western Portugal along the Atlantic coast of Spain to the northern slopes of the western Pyrenees, where its inland distribution is restricted by the mediterranean climate of the central Spanish mesetas. From west to east one can differentiate a cline in the formation of the 3 primary ribs of the elytra, which are distinct in western populations but only slightly apparent in eastern populations. According to BREUNIG *C. lineatus* is subdivided into 5 sub-species by these characters. As a result of our measurements we can show that the thickness of the elytra itself is closely correlated with the formation of the ribs, it increases from east to west. Nearly within the area of the Basque country *C. lineatus* confronts its sister species, *C. splendens*. In sympatric populations we found high numbers of hybrids. In its nominate form *C. splendens* does not show any ribs on the elytra, but a little in the sympatric area. We compared the cline of "rib-formation" against various climatic factors. The increasing rib-formation is accompanied by increasing summer drought. This may be in correlation with the burrowing activities in *C. lineatus*.

LIFE HISTORY AND STRATEGIES OF SURVIVAL IN A DEME OF THE CARABID BEETLE *CARABUS AURONITENS* F. F. Weber, Zoological Institute of the University, D-44 Münster, FRG.

Since 1979 the dynamics of a deme of *Carabus auronitens* have been studied in the Westphalian Lowland (Germany). From April to June the deme reproduces. During the first 2-3 weeks the beetles show an intense surface activity, later on the surface activity is reduced and the beetles climb trees for food. The rate of egg production largely depends on weather conditions. Food was never found to be limited. Mortality is high at the end of the spring season. The surviving beetles show a well-filled fat body at the end of the reproduction period. They are dormant during 8-9 months. During this period fat body store is not completely consumed, but can be spent on early spring performances in the next year. Preimaginal development takes place in spring and summer. In autumn the newly hatched beetles show an obligatory ripening period. They are intensely active on surface and also climb trees. The weight increases within 3-4 weeks by about 55%. The data obtained do not point to regulatory processes; however, some phenomena can be interpreted as elements of a strategy of risk spreading.

QUANTITATIVE GENETIC MODEL OF LIFE HISTORY EVOLUTION IN *CALLOSOBROCHUS CHINENSIS* (BRUCHIDAE): DISPERSAL AND RESIDENT STRATEGIES. M. Shimada, Department of Biology, University of Tokyo, Komaba, Tokyo 153, Japan.

Wild strains of the azuki bean weevil, *C. chinensis*, have a few days of pre-oviposition period (p.o.p.) and a higher flight tendency. On the contrary, a laboratory strain (>45 yr) lacks p.o.p. and has a more fecundity per female and a higher carrying capacity. Those facts are inconsistent with r-K selection theory, and require a new model contrasting dispersal and resident strategies for understanding the evolution of stored product insects.

The present model supposed the situation that resource depression in a patch forces adults to disperse to a new patch, and that the longer p.o.p. causes the higher survivalship during dispersal but the smaller fecundity in a new patch. Suppose adult density in a patch, N_t , a phenotypic vector of life history traits, $\mathbf{x}_t$, and density dependent increasing function, $F(\mathbf{x}_t, N_t)$, then $N_{t+1} = F(\mathbf{x}_t, N_t)N_t$. Selection response of phenotypes is $\Delta\mathbf{x} = HPPF(\mathbf{x}_t, N_t)$, where P is a phenotypic variance-covariance matrix, H is a heritability one, and $\nabla F(\mathbf{x}_t, N_t)$ is a gradient vector. Simulations showed that a shorter p.o.p., a more fecundity and a higher carrying capacity evolved with a short dispersal demand, and that a longer p.o.p. and a smaller fecundity did with a long dispersal demand.

PREDACEOUS COCCINELLIDS IN THE SOUTHEASTERN U.S. COASTAL PLAIN: OBSERVATIONS ON OVERWINTERING AND SEASONAL BIOLOGY. S. H. Roach, USDA-ARS, Cotton Production Research Unit, P. O. Box 2131, Florence, South Carolina 29503, USA

The seasonal occurrence of common species of coccinellids that occur on field crops in the southeastern U.S. Coastal Plain was examined. Emergence from hibernation quarters by *Hippodamia convergens* (Guerrin Meneville) occurs from early March through mid-April and there are spring and fall reproductive periods in this species. Both *Coccinella septempunctata* L. and *Coleomagilla maculata* (De Geer) have reproductive periods similar to *H. convergens*, but their overwintering habits are slightly different. Incidental observations on other species are presented.

FEEDING BEHAVIOR IN THE ORTHOPTEROID INSECTS OF THE BALEARIC ISLANDS (SPAIN). S. K. Gangwere, Department of Biological Sciences, Wayne State University, Detroit, MI 48202, USA.

Little is known about food selection and feeding behavior in the Orthopteroidea of the Balearic Islands, Spain, which prompted the present investigation. The study began with a field survey of the islands of Menorca and Ibiza, leading to selection of two stations for detailed analysis: Santo Tomas, representative of Menorcan sublittoral grassland and scrub, and Na Xamena, of Ibizan coastal mountains and foothills. Following a detailed habitat analysis of each station, 10 species were investigated by the following means: field observation of behavior, study of mouthpart adaptation, analysis of feculae, and use of differential feeding tests. These disclosed that 1) the species have essentially similar food habits in the two stations notwithstanding the insular separation and certain disparities attributable to local host plant availability, and 2) their feeding is generally consistent with that of their taxonomic group throughout the Mediterranean.

THE EVOLUTION OF FEEDING PREFERENCES IN THE NORTH AMERICAN TIGER SWALLOWTAIL BUTTERFLIES, *PAPILIO GLAUCUS* (Papilionidae). J. M. Scriber, M. Ayres and R. C. Lederhouse, Department of Entomology, Michigan State University, East Lansing, Michigan. 48824

The eastern tiger swallowtail butterfly, *Papilio glaucus* L. is the most polyphagous species of all 563 species of the Papilionidae family in the world. It feeds on dozens of genera from at least 13 different families of plants. Of particular interest is the geographic variability in host choice (i.e. local preferences). We will describe a new and previously undescribed ecological factor (i.e. temperature) influencing local host plant choices across the range of latitudes occupied by *P. glaucus* in North America (25°N-70°N). We will also address differential in behavioral acceptability and the genetically based detoxication abilities for larvae of various subspecies on plants of the Salicaceae, Magnoliaceae, Lauraceae. We will also describe progress toward identification of the specific phytochemical basis of antibiosis and antixenosis in these *Papilio*/plant interactions

PLANT CONSTITUENTS DETERRING OVIPOSITION AND FEEDING BY *PIERIS RAPAE* ON AN UNACCEPTABLE CRUCIFER. J.A.A. Renwick, C.D. Radke and K. Sachdev, Boyce Thompson Institute, Ithaca, NY 14853, USA.

The host-range of the cabbage butterfly, *Pieris rapae* includes most crucifers and a few other glucosinolate-containing plants. Yet some crucifers are rejected by ovipositing females and by larvae. The presence of oviposition deterrents has been demonstrated for several unacceptable species. The active compounds in *Erysimum cheiranthoides* have been identified as strophanthidin-based cardenolides. Extracts of *E. cheiranthoides* also deter larval feeding, but the most active constituents are not the oviposition deterrents. A different group of cardenolides is responsible for rejection by larvae. Several known cardenolides have been tested in oviposition bioassays, but few are active as deterrents. Comparative structure-activity relationships for oviposition deterrents and feeding deterrents are being developed.

RESPONSE TO PLANT ODOURS BY THE DIAMONDBACK MOTH *PLUTELLA XYLOSTELLA* (LEPIDOPTERA: PLUTELLIDAE) AND IDENTIFICATION OF THE ACTIVE COMPOUNDS. K.A. Pivnick*, B.J. Jarvis, E.W. Underhill, G.P. Slater. Plant Biotechnology Institute, NRC Canada, Saskatoon, Saskatchewan, S7N 0W9 Canada; and C. Gillott. Dept. of Biology, University of Saskatchewan, Saskatoon, S7N 0W0.

The diamondback moth is an oligophagous insect feeding exclusively on the Cruciferae. It is also a long-distant migrant, flying north into Canada each spring from the southern U.S. Thus, host location plays an important role in its life history. We have developed both a behavioural and an electrophysiological bio-assay to examine the moth's response to cruciferous plant volatiles. Attraction to these volatiles increases with age (at least up to 7 days) in both sexes. In females, attraction is stronger in individuals which are mated and ready to lay eggs. [Therefore, the age at which females are attracted to host plant odours depends on the rate at which females mature sexually which in turn depends on environmental conditions for the adult: both crowding and the absence of plants slow sexual maturation.] Screening to identify the bio-active compounds has so far implicated a minimum of three groups of compounds one of which acts synergistically with the other two. These results will be discussed in relation to the insect's migratory habit and host location strategy.

REPRODUCTIVE ALLOCATION IN THE WESTERN TREE-HOLE MOSQUITO, *Aedes sierrensis*. J.J. Hard, Department of Biology, University of Oregon, Eugene, Oregon USA 97403-1210.

Larval *Aedes sierrensis* from three populations in western North America were reared under varying laboratory conditions of temperature, food level, and larval density in a four-factor composite design. Variation in egg and clutch size of the adult females was measured to determine whether these environmental factors affected patterns of reproductive effort. Egg size varied within and among clutches of the same female and within and among factors. Clutch size varied temporally within females and both within and among factors. Interactions among factors had significant effects on egg and clutch size.

REPRODUCTIVE STRATEGIES OF A TORRENTICOLOUS INSECT (DIPTERA: DEUTEROPHLEBIIDAE). Gregory W. Courtney, Department of Entomology, University of Alberta, Edmonton, Alberta, T6G 2E3.

Mountain midges (Diptera: Deuterophlebiidae) are a seldom studied, yet widespread and seasonally-abundant aquatic insect in western North America. Relatively little is known about the ecology of these unusual inhabitants of torrential streams, especially regarding life histories. The objectives of this research were to characterize and contrast the life histories of several species of Nearctic Deuterophlebiidae, including descriptions of swarming and oviposition, and determination of fecundity and phenologies. Data were gathered for populations throughout western North America, though most observations pertained to Pacific Northwest Deuterophlebiidae.

Adult mountain midges emerge early in the morning, do not feed, and survive for only a few hours. For most species, flight activity begins between 0700-0900h and lasts ca. 2 hours, a period corresponding to the longevity of the adult male. The male is confined to an aerial existence, characterized by continuous flight over the water, often in large, well-defined swarms. Females spend relatively less time in flight, with the majority of their life in search of oviposition sites. Oviposition is active, beneath the water, and on the same substrates inhabited by the immature stages. The relatively low fecundity, ranging from ca. 50-200 eggs/female, is dependent on female size, and varies with species. Parthenogenetic development is evident in northern populations of one widespread Nearctic species. Highly asynchronous life histories are characteristic of most mountain midges, with hatching of eggs and adult emergence usually extending 2-3 months. This strategy is adaptive for deuterophlebiids in western streams, where frequent and unpredictable flooding may cause extensive substrate scouring, and correspondingly high mortality of immature stages.

THE IMPACT OF METHOXYCHLOR ON DRIFT OF AQUATIC INSECTS IN THE SASKATCHEWAN RIVER SYSTEM. L.M. Dosdall* and D.M. Lehmkuhl, Department of Biology, University of Saskatchewan, Saskatoon, Saskatchewan, Canada S7N 0W0.

The impact of methoxychlor treatment (0.3 ppm for 15 min) on drift of aquatic insects inhabiting the Saskatchewan River System was compared at three downstream sites (which were 21, 38 and 107 km from treatment), relative to an upstream untreated site. Treatment caused catastrophic drift at all downstream sites, but considerable variation occurred in the magnitude of drift increases between sites. Catastrophic-phase drift of species could be grouped into three categories based on the times of their greatest drift density. Methoxychlor treatment initiated or increased drift of several species which normally showed little or no propensity to drift. Closely related taxa showed similar drift patterns during the catastrophic phase.

For all species studied, comparisons of 24 hour drift densities during the days preceding and proceeding the catastrophic phase indicated significant differences at one or more of the downstream sites, but not at the untreated site. Methoxychlor impact on drift was species-dependent and extended beyond the time when catastrophic drift ended.

PERTURBATION OF THE AQUATIC INVERTEBRATE COMMUNITY OF BOG PONDS BY THE INSECTICIDE FENITROTHION. W.L. Fairchild, Department of Biology, University of New Brunswick, Fredericton, N.B., Canada E3B 6E1

In June of 1984 and 1985, fenitrothion was applied experimentally to acidic (pH 4) bog ponds at operational rates for forestry of two-times 210 g active ingredient per hectare. Maximum recorded postspray insecticide residue concentrations in water ranged from 42 to 81 ug/L. Six weeks after spraying, concentrations in water ranged from non-detectable to 0.06 ug/L. However, residue traces reappeared one year after spraying in water (0.3 ug/L), sphagnum moss (8-10 pg/g), and sediment (<0.01 pg/g). Total aquatic insect density was reduced and took over 12 months to return to control densities. Nematodes and annelids became more abundant after spraying, while most insects became less abundant. Chironomids and ceratopogonids, which were numerically dominant, had their abundance reduced by more than half. Other insect groups most affected include, Coleoptera, Hemiptera, and Odonata. Gyrinidae, initially eliminated by spraying, increased above prespray levels by the end of summer.

COMPARISON OF INSECT TRAPPING METHODS AFTER A RANGE FIRE. James D. Hansen. USDA-ARS, Utah State University, Logan, Utah 84322.

Different insect trapping methods were compared on recently burned and nearby unburned rangeland in the Great Basin of western Utah, U.S.A. Diptera was the most dominant group obtained from any of the traps. Winged traps collected the most specimens, but had the fewest number of species. This was the most inadequate method because of difficulty in removing specimens from the adhesive-covered wings. Water traps collected the most species at either site. Weekly collections of the pitfall traps at the unburned site had significantly more specimens and species than those from the burned site. Malaise traps were the most convenient, and large numbers of specimens and species were collected from both sites. Black Malaise traps collected more specimens, particularly at the burned site, than white Malaise traps, although this difference was not significant.

IMPACT OF HEATHLAND BURNING ON THE INSECT COMMUNITY.

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Heathland is a threatened biotop in Western Europe. Management is essential to maintain this biotop. This paper will examine the effects of burning management on several insect groups (i.e. Coleoptera, Hemiptera and Formicidae).

In the year following the fire the presence of a large number of 'typical' heathland insects was recorded. Insects are able to survive burning in the litter and in grass-tussocks. Xerophilous species become very abundant in the younger heather stands. Several species, f.i. *Formica sanguinea* Latreille (Hym., Formicidae) and *Coranus woodroffei* Putschk. (Heteroptera) are restricted in their occurrence to heather stands with plants over 12 yr of age. *Calluna*-stands aged between 0 and 10 years have a similar insect community structure. The insect fauna of stands with dominance of grasses are not comparable with these heather stands. The main problem in heathland management is the fact that grasses are taking over the dominance. If hardly any heather is left, the phytophagous insects of heather diminish or disappear. Intensive management is essential for maintaining the biotop. Managers should be aware of the following facts: 1. Several animal species are restricted to the old *Calluna*-stands; 2. Sod cutting is much more radical than burning or mowing, and should be done on a small scale only.

MODIFICATION OF PLANT-INSECT RELATIONS BY AIR POLLUTANTS: PRIMARY MECHANISM BY WHICH SULFUR DIOXIDE ENHANCES SUCCESS OF *EPILACHNA VARIVESTIS* MULSANT (COLEOPTERA: COCCINELLIDAE) ON *GLYCINE MAX* (L.) MERR. P. R. Hughes* and M. L. Volland, Boyce Thompson Institute for Plant Research, Cornell University, Ithaca, New York, USA 14853.

Success of Mexican bean beetle (MBB) on soybean is increased by exposure of plants to SO₂. The mechanism involved was elucidated in a series of experiments. First, the relationship between relative consumption and growth rates indicated increased feeding to be responsible for altered success. Secondly, carbohydrate analyses showed that total soluble carbohydrates of fumigated leaves was much higher than that of corresponding control leaves, and concentrations of sucrose, fructose, and glucose (known feeding stimulants) were increased 40-50% by the treatments. Thirdly, ability of the beetles to respond to differences in sugar content of the magnitude produced by pollutant exposure was demonstrated clearly in feeding choice assays using filter-paper discs impregnated with mixtures of the sugars. Thus, the primary mechanism by which SO₂ increases success of MBB on soybean appears to be increase in foliar concentration of stimulatory sugars, which, at least in part, is a consequence of pollutant interference with phloem loading and translocation of sugar from affected leaves.

INFLUENCE OF MAN'S ACTIVITIES ON SOME EUROPEAN MOUNTAIN INSECT COMMUNITIES. J.R. Haslett, National Park Administration, Doktorberg 6, D-8240 Berchtesgaden, FRG.

Mountain ecosystems are known to be extremely sensitive to human interference, not least through winter tourism. Skiing alters soil structure and vegetation cover in a manner similar to 'trampling', but over vast areas. The consequences for the insect communities are great.

Comparisons of ski slope communities of Syrphidae (Diptera), Carabidae (Coleoptera) and Orthoptera with equivalent communities on control sub alpine meadows in the Austrian and West German Alps have demonstrated that:

1) Species richness and diversity do not provide an adequate means of characterizing these communities for purposes of habitat evaluation.

2) Knowledge of autecologies allows a more accurate interpretation of the situation: Specialist insect species tend to be lost from the ski slopes. Populations of generalists are not strongly affected by skiing.

Such information, when combined with other variables in a computer based 'Geographical Information System', can provide a means of predicting the changes in insect distribution and community structure which could occur as a result of implementing or maintaining particular types of land use.

CANOPY FOGGING TO DELINEATE ARTHROPOD DISTRIBUTION AS A LIMITING FACTOR FOR ENDANGERED HAWAIIAN FOREST BIRDS. W.C. Gagné*, and S.L. Montgomery, Department of Entomology, Bishop Museum, Honolulu, Hawai'i, U.S.A. 96817

About 30 of the 55 species of birds on the U.S. Endangered Species List are Hawaiian forest endemics. Most of these forest birds are at least partly insectivorous. We have sampled canopies of dominant trees in some of their habitats on altitudinal transects on two mountains on Hawai'i I. using pyrethrins to dislodge canopy arthropods. Samples were categorized by their diversity, richness, biomass, quality as a food source for birds, and penetration by alien arthropods. There were significant differences in the canopy arthropods relevant to insect dependent birds. Attention is needed for broader approaches to the conservation of legally protected species in natural habitats to include management of the insect resources.

THE STRUCTURE AND STABILITY OF INSECT COMMUNITIES IN PADDY FIELDS. Chen Changmin*, Wan Fanghao and Yan Zhongcheng, Laboratory of Insect Ecology, Hunan Agricultural College, Changsha, Hunan 410128, P.R. China.

The structure and stability of insect communities in paddy fields was studied in Changsha, China, between 1983 and 1987. Fields were treated under three management levels: integrated control (I), excess use of insecticides (E), or zero spraying of insecticides (O). Results are reported with reference to: (1) species composition of insect communities; (2) the dominant degree of dominant species; (3) diversity analysis of communities; (4) evenness analysis of communities; (5) similarity analysis of communities; and (6) stability analysis of communities.

EVALUATION OF CRICOTOPUS MYRIOPHYLLI (DIPTERA: CHIRONOMIDAE) AS A POTENTIAL BIOCONTROL FOR EURASIAN WATER-MILFOIL (MYRIOPHYLLUM SPICATUM L.) Ian V. MacRae, Dept. of Biology, University of Victoria, Victoria, B.C. Can. V8W 2Y2.

Myriophyllum spicatum is a rooted aquatic macrophyte which spreads rapidly, mostly by asexual fragmentation. Introduced to B.C. in the early 1970's, it is now considered a major problem in many tourist areas of the province.

In the early 1980's, many well-established weed beds in the Okanagan Valley lakes failed to surface and flower. The cause was traced to the feeding damage of larvae of several species of aquatic insects. The majority of this damage was attributed to the larva of an undescribed chironomid (since named Cricotopus myriophylli Oliver, after its association with the plant).

This paper presents some of the research being conducted to evaluate this non-biting midge as a potential biocontrol agent for milfoil. Results indicate that C. myriophylli larvae feed on the meristematic tissue of the plant thereby suppressing growth. Observations on life history, host-preference, and rearing will be presented.

THE UTILIZATION OF STREAM INSECTS IN SEMI-NATURAL REARING OF COHO SALMON ONCORHYNCHUS KISUTCH (WALBAUM). J.H. Mundie, Department of Fisheries and Oceans, Pacific Biological Station, Nanaimo, B.C. V9R 5K6.

Coho salmon smolts were raised in a semi-natural channel alongside a river to reduce the costs of conventional hatchery methods by providing the fish with natural (insect) foods and by re-cycling uneaten artificial fish-food and wastes into insects. Questions were: what quantity of insects would be available as food for the fish, and what changes in numbers and species of insects would occur in response to organic enrichment? About 263,000 smolts were raised at a density of 375/sq.m. at time of release. Insects in the downstream riffle areas of the channel increased from 30,000/sq.m. in March to 350,000/sq.m. in December. Over 70 species occurred, the list being the same at the top and bottom of the channel, but the numbers and proportions were substantially different. Alloperla sp. (Plecoptera), Paraleptophlebia sp. (Ephemeroptera), Rheotanytarsus sp. and Stempellina sp. (Chironomidae) were abundant upstream species while Phaenopsectra sp., Microsectra sp., Polypedilum sp., and Kiefferulus sp. (Chironomidae), were abundant near the outlet. The trend was a reduction in species sensitive to organic content, and an increase in chironomids with haemoglobin. Coho juveniles ate emerging insects throughout daylight hours, and in all months 85 percent of fish had significant amounts of insects in their diet. The results indicate that, within certain constraints, there is economic benefit to be obtained from using stream insects as a basis for the culture of salmonids.

#40

STUDIES ON THERMAL CONSTANTS AND SEASONAL OCCURRENCE OF THE HEMISPHERICAL BROWN SCALE SAISSETIA COFFEAE WLK. (HOMOPTERA: COCCIDAE). M.A. ALI*, S.A. EL-DESSOUKI, M.M. METWALLY and K.Y. EL-SHOUNY, Department of Plant Protection, Faculty of Agriculture, Al-Azhar University, Nasr City, Cairo, Egypt.

Population dynamic and seasonal occurrence of the Hemispherical Brown Scale (BHS), Saissetia coffeae Wlk. on guava trees were investigated through two consecutive years: 1984 & 1985. Results showed 4 peaks (March, May, Sept., Nov.) in 1984 and only 3 peaks (March, Aug., Nov.) in 1985. Consequently, the insect could develop into 3-4 generations annually. The effect of weather factors on the population density was discussed.

Developmental threshold of S. coffeae was calculated as 11.4 C. A total of 163.09, 177.58, 178.71, 354.83 and 874.2 thermal units (T.U.) or day-degrees were required for the development of immature and mature stages of this species. Causes of variations in the insect phenology from 1984 to 1985 were discussed on the basis of thermal units accumulation. These calculations were also applied for forecasting the peaks of the insect activity.

#41

THE SPATIAL AND TEMPORAL DISTRIBUTION OF ENTOMOFAUNA IN A QUARRY POND. I. Ansaloni, A. Spampinato and R. Zunarelli-Vandini, Department of Animal Biology, University of Modena, 41100, Modena, Italy.

Quantitative and qualitative sampling of the macrobenthos, especially insect larvae, was carried out between 1985 and 1986 in an artificial pond derived from an open quarry (9700 sq.m.; maximum depth 4.5 m). Information concerning physico-chemical variables was also collected. The pond is fed from the water bearing stratum and lacks an effluent. It shows wide seasonal variations in depth. Thermal stratification of the pond and bottom layer oxygen deficiency were not detected.

The spatial distribution and temporal succession of the littoral and benthic macrofauna is described and discussed. Biological and chemio-physical data allow the evaluation of the trophic condition of the pond.

#42

FEEDING OF BITING MIDGES (DIPTERA, LEPTOCONOPIDAE) ON LIZARDS. G.A. AUEZOVA*, Z.K. Brushko, R.A. Kubykin. Institute of Zoology of the Kazakh Academy of Sciences, Alma-Ata 480032 USSR.

Biting midges Leptoconops specialis and L. minutus attacked resting or hunting reptiles at the desert mountains of Dzhungarsky Alatau (South-East of Kazakhstan). Eremia velox, E. intermedia, Phrynocephalus versicolor are among their providers. Females of biting midges sat on the stomachs, necks, heads and extremities of lizards, mainly casting their coat. Attacks were tangible for lizards – they tried to get rid of bloodsuckers. Females took the full portion of blood during 2,5–10 minutes of feeding. It is known, that biting midges Leptoconops feed on mammals and birds. Our observations extend the circle of their providers and are of interest to understanding of origin of bloodsucking.

#43

GENERALIST PREDATORS AS A SELECTION PRESSURE FOR NARROW HOST RANGE IN HERBIVOROUS INSECTS. E.A. Bernays, Division of Biological Control, University of California, Berkeley, 1050 San Pablo Avenue, Albany, CA. 94706, USA.

The background is given for development of alternative or additional reasons for the generally narrow host ranges found in herbivorous insects. Chemical bases or mating requirements are found to be inadequate. The role of natural enemies is considered. The possibility that specialist parasitoids provide a selection pressure for host switching and increased host range is contrasted with the possibility that more generalist predators provide a selection pressure for narrow host range. A corollary of this is that polyphagous herbivores are relatively vulnerable to generalist predators. Results in three different systems are presented which support this thesis.

#44

SPATIAL HETEROGENEITY OF INSECT-PLANT RELATIONSHIPS IN THE SUBARCTIC. I.A. Bogacheva, Institute of Plant & Animal Ecology, USSR Academy of Sciences, Sverdlovsk 620 008, U.S.S.R.

Since 1970 insect groupings on the common tree and shrub species and leaf consumption have been studied in the Low Ob region and on the Polar Urals. Biotopical variability was shown to be the highest as compared with other (geographical, local, individual) forms of spatial heterogeneity; the differences of leaf consumption in various biotopes can be 10–15-fold. Microclimatic conditions are believed to be responsible for biotopical variability. Local differences in herbivory are low; individual variations also were shown to be not higher than two-fold. We believe that plant chemistry does not concern to individual variations; induced chemical defence (long term effect) was demonstrated only in the most favourable biotopes. The herbivory on Salix phylicifolia declines abruptly after the year of heavy injury, when the mean losses for the whole biotope were 23%. Consumption in such biotopes remains nevertheless the highest, because they continue to be attractive for phyllophagous insects.

#45

DEVELOPMENTAL RATE OF THE SQUASH BUG, ANASA TRISTIS (HETEROPTERA: COREIDAE) AT CONSTANT TEMPERATURES AND ON MULTIPLE HOSTS. E.L. Bonjour* and W.S. Fargo, Department of Entomology, Oklahoma State University, Stillwater, Oklahoma, USA, 74078-0464.

Developmental rates of the squash bug, Anasa tristis DeGeer, were observed at 12 constant temperatures between 20.0 and 40.0°C on yellow straight neck squash. Times required for development for each life stage, as well as total development time, followed the classical "backwards-J" shape for each temperature. A nonlinear biophysical model was fit to data representing each individual life stage as well as to several combinations of life stages. In most cases, a four-parameter model was selected with high temperature inhibition.

The individual models indicate that the use of heat unit accumulation techniques to predict development times are valid within the linear response range between 23.3 and 31.3°C. Within this temperature range, A. tristis requires a mean of 379.8 degree days above a developmental threshold of 15.6°C. Development time was constant for each life stage as well as for total egg to adult development. The mean degree day accumulations were not significantly different across temperatures but development times in days were significantly different for each case.

Development of the squash bug was also observed on six cucurbit cultivars at a constant temperature of 26.7°C. On pumpkin and squash seedlings, 87.9 and 55.0% of the insects had complete development, respectively. Only six of 60 insects reached the adult stage on watermelon and only one insect became an adult on buffalo gourd. No survival occurred on cucumber or muskmelon with all insects dying in the second instar. Death in this early stadium may indicate an antibiotic effect.

#46

LES ESPÈCES CULICIDIENNES (DIPTERA: CULICIDAE) COLONISANT LES CREUX D'ARBRES ET LES VIEUX PNEUS AU QUÉBEC: CONSIDÉRATIONS ÉCOLOGIQUES ET PERSPECTIVES ÉPIDÉMIOLOGIQUES.

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Les creux d'arbres du sud du Québec constituent des gîtes larvaires pour *Ae. triseriatus*, *Ae. hendersoni* et *An. barberi*; de leur côté, les pneus abandonnés renferment *Ae. triseriatus*, et *C. restuans*, espèces dominantes accompagnées de *C. territans*, *C. pipiens*, *Cu. impatiens* et *An. punctipennis*. Bien que dominé par *Ae. triseriatus*, les densités larvaires dans les creux d'arbres demeurent faibles alors que dans les vieux pneus, elles peuvent atteindre plusieurs centaines au litre pour les espèces dominantes. La nature des essences forestières et la hauteur des creux d'arbres sont des facteurs à considérer pour comprendre la distribution des espèces culicidiennes tout comme le sont pour les vieux pneus le lieu et l'exposition à la lumière. Vectrices potentielles d'arbovirus pour certaines espèces, le succès d'expansion des culicidés est favorisé par les activités humaines. Le passage d'*Ae. triseriatus* de son milieu naturel à un milieu artificiel est manifeste et peut entraîner des conséquences épidémiologiques.

#47

DENSITY-DEPENDENCE IN MATURATION TIME: EXPERIMENTS AND MODELS OF ITS EFFECTS ON A HOST-PARASITOID SYSTEM.
S. Brault, Imperial College at Silwood Park, Ascot, Berks., SL5 7PY, U.K.

The influence of an increase in maturation time with density on the population dynamics of the stored-product moth *Corcyra cephalonica* (Staint.) is investigated in a single-species simulation model. Results from experiments on the response of its pupal parasitoid, *Antrocephalus pandens* (Hymenoptera: Chalcididae) to host size and age are presented. Female *A. pandens* adjust the sex of their offspring according to these host characteristics. The model is extended to include the parasitoid species and the observed density-dependence in host size.

#48

RAPID LIFE HISTORY EVOLUTION OF A SEED-FEEDING BUG, AND A DIVERSE GUILD OF SEED PREDATORS. S.P. Carroll* and J.E. Loye, Dept. of Biology, University of Utah, SLC, UT 84112.

Jadera haematoloma (Hemiptera: Rhopalidae) specializes on seeds of the Sapindaceae. Populations occur on native host plants in Oklahoma USA and disjunctly in south Florida USA, and on a recently introduced host in central Florida. Life history comparisons were made between these regions, which differ in the schedule of food availability and thermal seasonality: OK - seasonal food availability, cold winter; C. FL - seasonal food availability, mild winter; S. FL - continuous food availability, mild winter. S. FL bugs have the greatest body size, development time, egg size, and incubation time, and are least fecund. C. FL bugs are also large-bodied, but have the smallest eggs and most rapid incubation time, intermediate development time, and are most fecund. OK bugs are smallest-bodied and develop most rapidly, but are intermediate in egg size, incubation time and fecundity. Only in Oklahoma is there a true diapause, apparently induced by photoperiod. All populations differ in beak length, which is directly correlated with seed defense by the hosts. These differences, and the rapid evolution (50 yrs) of novel trait values in Central Florida, are discussed in relation to ecological differences between the regions. Only in South Florida are competing seed predators abundant: two lycaenid butterflies, *Hemiargus thomasi* and *Chlorostymon simaethis*, and a parasitic wasp. The larval biology of these competitors is also presented.

#49

Arthropods as Mediators of Nutrient Cycling. T.A. Christiansen* and J.A. Lockwood, Dept. Plant, Soil and Insect Sciences, Univ. Wyoming, Laramie, Wyoming, U.S.A.

The role of arthropod populations in nutrient cycling in a semi-arid *Artemisia* (sagebrush) and *Purshia* (bitterbrush) mountain habitat at an elevation of 2400m was investigated in southeastern Wyoming. The impacts of brush management practices on the arthropod ecology were monitored and modelled. Arthropod densities were negatively affected where brush was managed by either application of herbicide or mowing. However, the microhabitat of decomposer arthropods was an important component in assessing the impact of management strategies. Mowing caused greater damage than herbicide applications to arthropod communities under sagebrush but less damage to communities in exposed areas. Arthropods significantly reduced foliage biomass in control, mowed and herbicide treated areas but increased foliage biomass in burned areas. Root biomass and litter decomposition were positively correlated with arthropod densities. Nutrients (N, C, K, Ca, P, Mg and Na) in litter and foliage were also affected by the arthropods in this habitat.

#50

OVIPOSITOR MORPHOLOGY AND OVIPOSITION BEHAVIOR OF THE FEMALE COTTON BOLL WEEVIL, *ANTHONOMUS GRANDIS* BOH. (COLEOPTERA: CURCULIONIDAE).
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The cotton boll weevil, *Anthonomus grandis* Boh. has been reported to feed on several plants in the family Malvaceae including globemallow, *Sphaeralcea* spp., and cultivated cotton, *Gossypium hirsutum* L. Adult females prefer to feed on and oviposit in the buds and fruit of the cotton plant. While females will feed on globemallow, they will not oviposit in the flower buds unless the buds have been soaked in an aqueous extract of the cotton plant. Also, female weevils exhibit a decreased tendency to oviposit in cotton buds that have been treated with an aqueous extract of the globemallow plant. These results plus the observation that the female first probes a feeding hole with her ovipositor before depositing an egg in it suggest that chemosensory input may stimulate or inhibit oviposition. The ovipositor of the female cotton boll weevil was examined by scanning electron microscopy for the presence of sensilla that might facilitate the choice of a suitable oviposition site.

#51

FACTORS CONTRIBUTING TO HOST PLANT SPECIFICITY IN PREDATORY MITES OF THE GENUS *EUSEIUS* WAINSTEIN (ACARI: PHYTOSEIIDAE). B.D. Congdon*, School of Natural and Mathematical Science, Seattle Pacific University, Seattle, WA 98119 and J.A. McMurtry, Department of Entomology, University of California, Riverside, CA 92521.

The three native California *Euseius* species are polyphagous, facultative predators, but each shows remarkable host plant specificity. Measurement of life history parameters on *Citrus* spp., *Persea americana* Mill. (avocado), and *Quercus* spp. (oak) leaves indicated that all were equally suitable for *E. hibisci* (Chant), but *E. tularensis* Congdon survived and reproduced normally only on *Citrus*, and *E. quetzali* McMurtry exhibited a decline in fecundity on *P. americana*. In behavioral studies, *E. hibisci* preferred *P. americana* over lemon, *E. tularensis* preferred orange over *P. americana*, and *E. hibisci* showed no difference in response to orange and *P. americana*. Laboratory studies of competition between *E. hibisci* and *E. tularensis* demonstrated a mutually negative interaction, corroborating field collection data from areas of sympatry where *E. hibisci* is apparently restricted to *P. americana*.

These data imply that both direct interactions with the host plant and interspecific competition are factors contributing to host plant specificity in California *Euseius* species.

#52

ON THE FAUNA AND ECOLOGY OF THE MASS SPECIES OF NYCTERIBIIDAE (DIPTERA) IN KAZAKHSTAN; T.N. Doszhanov and A.J. Polkanov*. Institute of Zoology of the Kazakh Academy of Sciences, Alma-Ata 480032 USSR

10 species of bat flies: *Nycteribia quasiocellata*, *N. latreillii*, *Acrocholidia lindbergi*, *Phtiridium biarticulatum*, *Ph. szechuana*, *Basilis mon-golensis*, *B. rybini*, *Penicillidia dufourii*, *P. mon-ceros*, *P. sp.* – are distributed in Kazakhstan on Chiroptera of the mountain-desert and northern forest complexes (*Rhinolophus*, *Eptesicus* and *Myotis* bats). Special types of hosts' settlements are necessary for the life and reproduction of bat flies. Nycteribiidae are known only on the colonial bats in shelters with summer temperatures more than 15° and relative humidity near 90%. The mass hatching of bat flies from their puparia considers with the arrival and breeding of bats.

#53

GENETIC BACKGROUND OF THE WING POLYMORPHISM OF THE ORIENTAL CHINCH BUG, *CAVELERIUS SACCHARIVORUS* OKAJIMA (HETEROPTERA: LYGAEIDAE). K. Fujisaki Laboratory of Sugarcane Insect Pests, Okinawa Prefectural Agricultural Experiment Station, 4-222 Sakiyama-cho, Naha 903, Japan

The oriental chinch bug, *Cavelerius saccharivorus*, which is an important pest of sugar cane in the Southwest Islands of Japan, shows a wing polymorphism of brachypters and macropters. In the offspring of crosses between macropters, there is a strong tendency for macropters to increase to a high level with increasing nymphal density in both sexes. In the offspring of crosses between brachypters, the appearance rate of macropters attains a maximum value in moderately crowded conditions and conversely decreases to a lower level in more crowded conditions. Thus density response patterns in the determination of wing form are quite different between the offspring of different crosses, indicating that there is a genetic difference in the threshold response to nymphal density. As a result, in the field populations of this species, the frequency distribution of wing form in terms of the relative wing length changes with increase in the population density from a single modality biased toward the brachypterous form to bimodality with both macropterous and more extreme brachypterous forms. Ecological significance of such a wing polymorphism will be discussed with reference to the reproductive strategy.

#54

STRUCTURES DE POPULATION DE FORFICULA AURICULARIA (DERMAPTERA: FORFICULIDAE). J. Gingras, J.C. Tournier*, Département des Sciences biologiques, Université du Québec à Montréal, C.P. 8888, Succ. A, Montréal, Canada H3C 3P8 et M. Vancassel, Laboratoire d'Ethologie, Université de Rennes I, Avenue du Général Leclerc, 35042 Rennes-Cédex, France.

L'étude vise à comparer quelques paramètres décrivant la structure de plusieurs populations de *Forficula auricularia*. Les populations comparées sont celles de Vancouver (Colombie Britannique, Canada) (Lamb et Wellington, 1975), Pacé (Bretagne, France) et Deux-Montagnes (Québec, Canada). Les paramètres comparés sont la proportion des différents stades larvaires et des adultes de deux sexes sur le terrain du printemps à l'automne, la survie des adultes en hiver et les périodes de développement embryonnaire. Bien que les paramètres ne soient pas connus au même niveau de précision dans chacune des populations, il apparaît que des différences très nettes existent entre les populations de Pacé et de Vancouver d'une part et celle de Deux-Montagnes d'autre part.

#55

ANNUAL LIFE CYCLE OF SPIDER MITES AND INTERACTIONS BETWEEN SPIDER MITES AND THEIR PREDATORS ON DWARF BAMBOO LEAVES. T. Gotoh, Laboratory of Applied Entomology and Zoology, Faculty of Agriculture, Ibaraki University, Ami, Ibaraki 300-03, Japan.

Six spider mite species sympatrically inhabit dwarf bamboo leaves in Sapporo, and every developmental stages of each species were clearly separated and identified under dissecting microscope.

Five spider mite species, excepting for *Sasanychus akitanus* who was very rare on randomly sampled leaves, produced 4 or 5 generations a year, and overwintered either as egg, adult female or both on the leaves. Predators observed included two stigmæid species, at least 7 phytoseiid species and insect predators, i. e., gall midges, thrips and rove beetles. The maximal density appeared in spring for *Schizotetranychus celarius*, rove beetles and stigmæids, in summer for *Schizotetranychus recki*, *Aponychus corpuzae*, phytoseiid mites and gall midges, and in early winter for *Panonychus ulmi* and *Yezonychus sapporensis*. Interactions among tetranychids and phytoseiid mites, insect predators and the leaf hair density were systematically analyzed and their significance in the field was investigated.

#56

DENSITY-DEPENDENT PHENOTYPIC PLASTICITY IN THE AFRICAN ARMYWORM *SPODOPTERA EXEMPTA* (WALK.) (LEPIDOPTERA: NOCTUIDAE). A. Gunn, A.G. Gatehouse* and K.P. Woodrow, School of Animal Biology, University College of North Wales, Bangor, Gwynedd LL57 2UW, U.K.

S. exempta, in common with several other noctuids, exhibits a density-dependent phase polyphenism. The procrystic low-density (solitaria) form is regarded as primary and the distinctive physiological and behavioural characteristics of the heavily pigmented high-density (gregaria) form are interpreted as adaptations to accelerate larval development.

Moths from larvae of the two forms differ markedly in the quantities of their glyceride reserves and in fecundity, as well as in their capacities for prolonged flight. These differences are discussed in relation to migratory and reproductive strategies in this armyworm species.

#57

INFLUENCE OF INTER- AND INTRA-SPECIFIC VARIATION AMONG CITRUS SPP. ON THE GROWTH OF THE CALIFORNIA RED SCALE, *AONIDIELLA AURANTII*, AND SUSCEPTIBILITY TO PARASITISM BY *APHYTIS MELINUS*. J. Daniel Hare,* Dickie S. Yu, and Robert F. Luck, Department of Entomology, University of California, Riverside, California, USA, 92521.

Aphytis melinus allocates sex of its offspring based upon the size of its host, *Aonidiella aurantii*, females being allocated to scales greater than 0.39 sq. mm. Host plant factors affecting either growth rate or ultimate scale size will influence the population dynamics of *A. melinus* through their effects on parasitism rate and parasitoid sex ratio. We quantified the variation in scale growth rate and ultimate size when reared on different substrates (leaves vs. wood) within and among four citrus species (lemon, mandarin, orange, and grapefruit) growing adjacently and determined if variation in scale growth and size could be explained adequately by variation in concentrations of plant nitrogen compounds within and among species. On leaves, ultimate size differed among sites within species but not among species. Growth rates appeared fastest on lemon. Grapefruit had the highest concentration of soluble nitrogen and lemon the lowest.

#58

ON ESTIMATING UNCERTAINTY IN INSECT POPULATION GROWTH RATES OBTAINED FROM LIFE TABLE EXPERIMENTS. D.B. Hogg*¹ and S.Y. Chen², ¹Department of Entomology and ²Department of Statistics, University of Wisconsin, Madison, Wisconsin 53706, USA.

Methods for estimating bias, standard errors, and confidence intervals for population growth rate parameters were evaluated. Specifically, two computer-intensive approaches for estimating uncertainty, the Bootstrap and the Jackknife, were used to analyze life table data from hypothetical populations, and the results were compared. The primary conclusions from this study are: (1) The finite rate of increase is preferable to the intrinsic rate of increase as the growth rate parameter for statistical analysis. This is due to the different distributional properties of the parameters. (2) In general, the Bootstrap and Jackknife analyses produced similar results. However, the most accurate confidence intervals were usually obtained from the Bootstrap using "Efron's bias-corrected" method with an ad hoc adjustment for small sample size. These results are discussed in the context of other recent work on this topic and with regard to practical considerations.

#59

GRADED RESPONSE TO PHOTOPERIOD IN TERMINATION OF SUMMER DIAPAUSE IN THE TWO UNIVOLTINE ZYGAENID MOTHS. M. Ishii* (Entomol. Lab., Coll. Agr., Univ. Osaka Pref., Sakai, Osaka, 591 Japan) and Y. Johki (Dept. Zool., Fac. Sci., Kyoto Univ., Sakyo, Kyoto, 606 Japan).

The univoltine zygaenids, *Pryeria sinica* and *Elcysma westwoodii*, pass the summer as diapausing pupa and prepupa, respectively. The pupal stage of *sinica* lasts for more than 4 months from June to October, while the prepupal stage of *westwoodii* for about 2 months from June to August. In order to elucidate the factors affecting the diapause termination, diapausing insects were exposed to different temperature and photoperiodic conditions.

In both species, durations of the diapause stage were strongly affected by photoperiod: they gradually decreased with the decrease in photoperiod. The results may demonstrate that the diapause termination in the present two zygaenids is controlled by a graded response to daylength. In *sinica*, in addition to this, larval long day shortened the pupal stage. Such responses are considered to ensure synchronized development and reproduction in a population.

#60

WHAT IS THE BEST HOST PLANT? - IN CASE OF A COREID BUG, *CLETUS TRIGONUS* THUNBERG (HETEROPTERA: COREIDAE)-. K. Ito, National Agriculture Research Center, Yatabe, Tsukuba, Ibaraki 305, Japan.

A desirable host plant for an insect has 1) a short developmental period, 2) a high survival rate, 3) a short preovipositional period, 4) high fertility and 5) long longevity. Ideally the best host plant satisfies all of these conditions. But there are few studies verifying this hypothesis. *Cletus trigonus* is a common coreid bug in southern Japan, China and Southeast Asia. This bug usually feeds on ears of Amaranthaceae or Chenopodiaceae. The development, oviposition and longevity of this bug were investigated by feeding it various plant seeds. Among the various seeds used, *C. trigonus* was able to emerge to adulthood by feeding on *Amaranthus viridis*, *Chenopodium serotinum*, *Polygonum persicaria* and wheat. Although *A. viridis* and *C. serotinum* are original host plants of this bug, they were not superior to other food plants in all of the points mentioned above. When *C. trigonus* fed on wheat which is not an original host plant, it took a long developmental period and the number of eggs laid per day was small. But the adult longevity was 3 times longer than that fed on *C. serotinum*. Also the fertility was comparable to when fed on *C. serotinum*. Since the actual longevity of this bug and available period of a host plant may be shorter than the bug's physiological longevity in the field, host plants which secure short developmental period and high fertility in early adult stage will be the best for *C. trigonus*.

#61

PARASITOIDS OF *PIERIS* LARVAE: ARE THEY SHARING THE SAME HOST? K. Iwao, Entomological Laboratory, College of Agriculture, Kyoto University, Kyoto 606, Japan.

Intra- and interspecific relationships were investigated among larvae of two tachinids and a braconid parasitizing caterpillars of the genus *Pieris* (Lepidoptera: Pieridae). *Epicampocera succincta* Meigen and *Compsilura concinnata* Meigen (Diptera: Tachinidae) are both solitary parasitoid flies, the former a specialist on the genus *Pieris* and the latter a generalist on more than 200 species, while *Apanteles glomeratus* Linnaeus (Hymenoptera: Braconidae) is a gregarious parasitoid also specializing on *Pieris* larvae. Fifth instar larvae of *Pieris* species that were collected from the field were reared and dissected to determine the rates of super- and multiparasitism. In *E. succincta*, superparasitism was similar to the case when there was only a single parasitoid and always resulted to the emergence of a single larvae with normal body weight. In contrast, *C. concinnata* showed a scramble-type of competition that resulted to individuals with reduced body weight. In case of multiparasitism, *E. succincta* never survived in the presence of either of the other two parasitoids while *C. concinnata*, although reduced in body weight, coexisted with *A. glomeratus*. The braconid wasp appeared not to be affected by the presence of the two tachinids.

#62

HELIOTHIS VIRESCENS (F.) OVIPOSITION ON *NICOTIANA SPECIES*. D. Michael Jackson*, R.F. Severson, and V.A. Sisson, Tobacco Research Laboratory, U.S. Department of Agriculture, Agricultural Research Service, P.O. Box 1555, Oxford, North Carolina, U.S.A., 27565-1555.

The ovipositional response of tobacco budworm, *Heliothis virescens* (F.) moths toward 70 assessments of *Nicotiana* species were evaluated by choice tests versus NC 2326 flue-cured tobacco in field cages during 1984-87 at Oxford, N.C. Egg laying on the various *Nicotiana* species ranged from nearly zero to over 100% of the number deposited on the flue-cured check. Additionally, tobacco budworm oviposition on 32 of the *Nicotiana* species was determined in no-choice tests in the same field cages in 1986-87. Results were similar between choice and no-choice type experiments. Measures of tobacco budworm ovipositional response were positively correlated to levels of divane diterpenes and sucrose esters found in the cuticular waxes of leaves from the *Nicotiana* species. Isolated fractions of these components stimulated tobacco budworm oviposition when applied to previously nonpreferred tobacco types in field-cage and laboratory bioassays. A dose-response relationship was developed between ovipositional response and the logarithm of total divane diterpenes in controlled experiments.

#63

EFFECT OF FIRE ON SOIL AND GROUND LAYER FAUNA IN SUBARCTIC BIRCH FOREST. S. Koponen, Department of Biology, University of Turku, SF-20500 Turku, Finland.

Effect of forest fire on soil and ground layer arthropod fauna was studied in subarctic mountain birch forest, Finnish Lapland (69°45'N). The fire destroyed about 35 ha of open birch forest in July 1985. The present material was collected in summer 1986, and a study of succession of fauna and flora has been carried out since then.

Density of soil microarthropods was slightly lower in burned than in control area. The composition of the Collembola fauna was at species level practically identical in burned and control area. Among Acari, Prostigmata was more numerous at burned sites and Oribatei, especially juvenile Brachychthoniidae, at control sites.

Density of soil and ground layer macroarthropods (spiders and insects), extracted by large Tullgren funnels, was clearly lower in burned than in control area.

Some ground-living groups, collected by pitfall traps, were more abundant (or active) at burned than at control sites; e.g. heteropterans (*Aradus lugubris*) and latridid beetles (*Corticaria* spp.) attracted by burned birches. Also ants (*Formica gagatoides* and *Leptothorax acervorum*) searching for nest-sites or foraging, and certain hunting wolf spiders (*Pardosa palustris*) were more active in open burned area than in control area.

#64

ECO-ETHOLOGICAL STUDY OF PREDATION BY A PONERINE ANT (FORMICIDAE, ECTATOMMINI) IN COFFEE PLANTATIONS. J.P. Lachaud, B. Corbara* and J. Valenzuela. Laboratoire d'Ethologie et Sociobiologie (UACNRS 667), Université Paris XIII, F-93430 Ville-taneuse, France and Laboratorio de Etologia, C.I.E.S., Tapachula 30700, Chiapas, Mexico.

Various experiments performed in Mexico with *Ectatomma ruidum* Roger allowed us to measure the greatest topographic range of effects resulting from a given colony's predation. Within this range, the number of available prey plays an important part on the activity level of forager workers. Nevertheless, there is a limit to the efficiency of provisioning related to the saturation of supplies in the nests. The action of the "archaic mass recruitment" exhibited by *E. ruidum* is evident when we consider the predation cinetics but this occurs only over very small distances (< 1m from the nest entrance).

The great flexibility of the predatory strategy used by *E. ruidum* and its efficiency near the nest entrance, combined with the high density of this species in coffee plantations, are responsible for *E. ruidum*'s role as one of the most important biological controls in this biotope.

#65

SEED DIVERSITY AND CALLOSOBROCHUS MACULATUS (FABR.) (COLEOPTERA: BRUCHIDAE) POPULATION DYNAMICS: A TEST OF POPULATION LOSSES CAUSED BY OVIPOSITION ON NONHOST SEEDS. W.O. Lamp, Department of Entomology, University of Maryland, College Park, MD 20742, USA.

Plant diversity is often associated with a reduction in herbivore population density. A number of factors can influence such a change, including the action of natural enemies or changes in insect colonization/reproduction in vegetation-diverse habitats. One common mechanism that has not been investigated in detail is the use of nonhosts as ovipositional sites by herbivores, leading to mortality of the immature stage. *C. maculatus* readily oviposits on various leguminous seeds in storage, however the larvae can only penetrate and survive in *Vigna sinensis* seeds. An experiment was conducted to investigate the influence of seed diversity on *C. maculatus* population dynamics, in which *V. sinensis* seeds in storage were diversified with *Phaseolus vulgaris* seeds in both additive and replacement series. As expected, population growth was reduced when the seed habitat was diversified, however density dependent mortality modified the influence of seed diversity. To evaluate these results, a model was constructed to simulate population dynamics based on patterns of oviposition, survival, and preference.

#66

MULTIVARIATE ANALYSIS OF COMPOSITIONAL CHANGES OF COMMUNITIES OF EPHEMEROPTERA (INSECTA) IN THE LABE BASIN, CZECHOSLOVAKIA - A COMPARISON OF METHODS. V. Landa*, T. Soldán and J. Lepš, Institute of Entomology, Czechoslovak Academy of Sciences, Branišovská 31, 370 05 České Budějovice, Czechoslovakia.

The mayfly communities from 150 localities of brooks, rivers, lakes and ponds from the Labe basin were quantitatively sampled in the two research periods (1950-65, 1970-85). Besides classical saprobiological methods, following methods of multivariate analysis were applied to evaluate the qualitative and quantitative changes in community composition: detrended correspondence analysis (DCA), agglomerative hierarchical classification and divisive hierarchical classification (TWINSPAN). Two designs of analysis were applied; in the first one, the samples from each period were corroborated separately to determine factors responsible for community differentiation in each period. In the second design, all the samples were corroborated together and changes in membership in clusters or shifts of localities in ordination space were taken as signs of community changes. Ordination of species corresponds well to the saprobiological indicator values of species. The TWINSPAN classification seems to provide the most informative results. The results of classifications provided good basis for subsequent construction of transition matrices.

#67

LIFE HISTORY STRATEGIES OF UNIONICOLA DIVERSIPES VIETS, 1926 A PARASITIC FRESHWATER MITE FROM INDO-BANGLADESH SUB-CONTINENT. M.Z.R. Majumder* and S. G. Pal, Department of Zoology, University of Calcutta, 35 B. C. Road, Calcutta 700 019, India.

Collection data from Bengal indicated that six definite life cycle stages of *Unionicola diversipes* occur in the host, *Lamellidens marginalis* and its medium. Only egg, protonymph, tritonymph and adult usually infest the mantle and gill of the host where as the two most active stages, i.e. larva and deutonymph are generally present in water of mussel culture. Protonymph and tritonymph are two quiescent stages. Two other inactive phases as larva prior to protonymphal stage and that of deutonymph prior to tritonymphal stage could also be isolated from mantle/gill. These two phases might be recognized as "transitions" (?) from larva to protonymph and from deutonymph to tritonymph. More than one stage of this parasite could be isolated from various organs of same host at the same time. Choice of various organs at different life stages as well as exploration of the host environment might be due to adaptation of the parasite.

#68

INDICE DE PREFERENCE DANS LE SYSTEME PREDATEUR-PROIES : SCIOMYZIDES-MOLLUSQUES.

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En présence de plusieurs espèces-proies, en proportions variables, un prédateur manifeste généralement une préférence plus ou moins marquée pour l'une d'entre elles. Le degré de préférence est mesuré grâce à des indices établis par comparaison des proportions de proies consommées (P) et offertes (N). Leur application au système Sciomyzides (Diptera) - Mollusques a permis de souligner l'intérêt de l'indice c de Murdoch, qui présente cependant certains inconvénients. Pour y remédier, nous avons modifié cet indice et défini un indice M :

$$M = \frac{P_1/N_1 - P_2/N_2}{P_1/N_1 + P_2/N_2}$$

Cette formulation apporte le double avantage de pouvoir calculer l'indice de préférence quelles que soient les proportions consommées de chacune des catégories de proies, et de varier dans des limites finies, de -1 à +1.

#69

AGE OF FEMALE BANKS GRASS MITE, OLIGONYCHUS PRATENSIS (BANKS) (ACARI: TETRANYCHIDAE), AFFECTS FECUNDITY, OFFSPRING SEX RATIO, AND DISPERSAL BEHAVIOR. D.C. Margolies* and J.A. Barron, Department of Entomology, Kansas State University, Manhattan, Kansas, USA 66506.

Banks grass mite populations utilize ephemeral resources/habitats. As habitats become unsuitable mites migrate to find new ones. Starvation and dehydration act as signals of resource/habitat deterioration. The degree of starvation or dehydration which triggers behavior leading to migration varies among individuals. Variation in dispersal behavior includes both genetic and non-genetic components.

Age of a mite accounts for much of the non-genetic variation in dispersal behavior. Daily egg production and the sex ratio of the offspring also vary with the age of a female mite. Tendency to disperse and reproductive output vary inversely as age increases. Offspring sex ratio decreases with age of the mother but is not clearly correlated with dispersal behavior or fecundity.

Dispersal, fecundity, and sex ratio are considered as components of mite fitness. The relationship among these traits are related to theories of colonization of new habitats, life history adaptation, and local mate competition.

#70

THE DUNG-BAITED PITFALL TRAPS. POSSIBILITIES IN THE STUDY OF DUNG-BEETLES COMMUNITIES OF SCARABAEODEA (COL.). J. M. Lobo, F. Martín-Piera (*) & C. M. Veiga. Museo Nacional Ciencias Naturales (C.S.I.C.): Entomología. c/ José Gutiérrez Abascal, 2; 28006-MADRID (SPAIN).

The authors compare the effectiveness of different models of dung-baited pitfall traps. Such analysis allowed them that: i) the most effective pitfall trap for collecting dung-beetles Scarabaeoidea, does not need to be placed in the field for a long time; ii) different diameters does not significantly modify the effectiveness of the traps; iii) the bait location determines a variation of the abundance but not of the richness; this variation principally affects, the abundance of the dominant species; iv) the bait sizes exercise an influence on the captures similar to that location, but not so intense. When both factors act synergistically, the number of specimens caught, is still most variable (greater or lower); v) One can be assured that only one model exists which reflects the abundance of the species which colonize and excrement after 72 h.; vi) This a delayed-action trap, so that it need to be placed 36 h. in the field to obtain a similar abundance what we observe -- with 6 and 24 h. sampling in feces; and vii) in spite of its effectiveness one must take into account this model's favoring of the hipophagic species.

#71

THE INTERPRETATION OF POPULATION CENSUS DATA. Jeffrey A. Millstein* and Alan A. Berryman, Department of Entomology, Washington State University, Pullman, Washington 99164-6432, USA.

Insect population census data are frequently gathered during routine surveys to determine the current status of pest populations and to estimate expected population trends, but rarely are they used thereafter. We show, using as an example data from gypsy moth egg mass surveys from 1910 to 1931, how important information on density-dependent and -independent factors, intra-specific competition, parasitism, predation, and management alternatives can be extracted from such data.

#72

DIFFERENTIAL TIMING OF PUPARIATION AND PUPATION OF THE FLESHFLY, BOETTCHERISCA PEREGRINA, BETWEEN DIAPAUSE- AND NONDIAPAUSE- DESTINED INDIVIDUALS.

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When fleshfly larvae are reared under a short day condition from the late embryonic stage through whole larval stage the resultant pupae enter diapause, whereas larvae reared under a long day condition become pupae developing continuously to adults. In diapause-destined larvae, 50% pupariation took place 38.5 - 41.5 hr after transferred to dry place. In nondiapaused-destined larvae, 50% pupariation occurred about 10 hr earlier. Pupation of diapause- and nondiapaused-destined animals took place 48-50 hr and 58 - 60 hr after the pupariation, respectively. Therefore, delay in pupariation time of diapause-destined larvae was entirely recovered by a shorter duration between pupariation and pupation. Morphological and biochemical studies on the processes of pupariation and pupation revealed that different amount of ecdysone and different duration of ecdysone action were required between pupariation and pupation.

#73

EXPERIMENTAL ANALYSIS OF THE FLIGHT ACTIVITY OF THE BROWN-WINGED GREEN BUG, PLAUTIA STALI SCOTT (HETEROPTERA: PENTATOMIDAE) USING AN AUTOMATIC DATA ACQUISITION SYSTEM. S. Moriya, Fruit Tree Research Station, Tsukuba, Ibaraki, 305 Japan.

P. stali is known as one of the most serious pests of tree fruits in Japan. Since the damage is caused by adults which invade the orchard from outside, it is important to investigate their flight activity for a thorough understanding of the life history of this species. An automatic data acquisition system with eight flight mills was developed for the determination of the following indicators of the flight activity of the adults: the total flight distance, the total duration of flight, and the average flight velocity. Although there were wide variations in the measurements among the individuals tested the data were analyzed in relation to the season, age, food conditions and photoperiod. It was demonstrated that on an average, adults which had overwintered exhibited a lower flight activity than those which appeared in the current year. The flight activity of the males of the laboratory population, tended to increase when the males received only water for 4 days prior to the measurements. The dissection of the adults collected in the field, showed that the effect of the amount of fat body and the degree of ovarian development on the flight activity was negligible. This fact suggests that tenatal flight may not occur in this species. No relationship was detected between the flight activity and the body size evaluated by the measurement of the wing length and pronotum width.

#74

AESTIVATION AND MIGRATION OF THREE SAWFLIES, *ATHALIA* SPP. (HYMENOPTERA: TENTHREDINIDAE) IN RESPONSE TO RESOURCE HETEROGENEITY. K. Nagasaka, Entomological Laboratory, College of Agriculture, Kyoto University, Sakyo-ku, Kyoto 606, Japan.

Seasonal occurrences of three sympatric sawfly species (*Athalia japonica* Klug, *A. rosae ruficornis* Jakovlev, and *A. lugens* Klug) feeding on cruciferous plants were examined and compared at two different habitats: open-land and mountainous areas. Resource abundance changed seasonally in characteristic patterns of respective habitats. On the open-land habitat, resources disappeared at mid-summer, while at the mountainous habitat, host plants were available throughout the growing season. Among the three species, only *A. japonica* did not show phenological synchronization with resource abundance at each habitat, and they aestivated during summer. The other two species were assumed to immigrate from the open-land to mountainous habitat to avoid food depletion in summer.

#75

POPULATION DYNAMICS OF THE PHYTOPHAGOUS LADYBIRD *EPILACHNA VIGINTIOCTOPUNCTATA* (COLEOPTERA: COCCINELLIDAE) UNDER A HUMID EQUATORIAL CLIMATE IN SUMATRA. K. Nakamura* (Dept. of Biology, Fac. of Science, Kanazawa Univ., Kanazawa, Japan) and I. Abbas (Dept. of Biology, Fac. of Science, Andalas Univ., Padang, Indonesia).

A population of the 28-spotted ladybird *E. vigintioctopunctata*, feeding on a shrubby weed *Solanum torvum*, was studied continuously from 1982 to 1985 in Padang, Sumatra by mark-recapture of adults and construction of life tables. Padang lies on the equator: the air temperature was quite constant at 27°C and the annual rainfall 4764mm without a distinct alternation of wet and dry seasons. The species reproduced successively during the study period, with 8 generations per year. The maximum amplitude of fluctuation in adult number was 290, forming 3 major peaks without clear relationships to climatic conditions. Increase and decrease of adult numbers in these peaks were gradual processes each lasting 3-5 months. The life tables show that: the peaks were caused by higher rates of survival in all stages from egg to adult for a few consecutive generations. After reaching a peak, a shortage of food due to overcrowding caused the population to fall to its lowest point. Second, parasitism by eulophid wasps killed a substantial portion of immatures. The Sumatran species had a much higher level of parasitism than Japanese conspecifics.

#76

GEOGRAPHIC VARIATIONS OF NYMPHAL DIAPAUSE IN THE SMALL BROWN PLANTHOPPER, *LAODELPHAX STRIATELLUS*. Hiroaki Noda, National Agriculture Research Center, Kannondai, Tsukuba, Ibaraki 305, Japan.

The small brown planthopper diapauses in third or fourth instar nymphs by short days and starts postdiapause development by the environmental change to long days. Since this species has a wide geographical distribution, differences in diapause among local populations in Japan were examined. As for diapause induction, the populations from north region diapaused facily and those from south region were reluctant to diapause. There was a clear geographic cline in critical photoperiod for diapause; the higher was the latitude of planthopper locality, the longer was the critical photoperiod. As for diapause termination, the diapausing nymphs received the increase in day length rather than absolute photoperiod as the termination stimulus. The populations from north region needed larger increase in day length for the stimulus than those from south region. Moreover, the northernmost population required longer period to become adult after the photoperiodic change than the other populations, and this was due to delay of first moult in postdiapause development. Each local population had its own nature of diapause which is supported by genetic basis.

#77

TEMPORAL VARIATION IN OFFSPRING FITNESS AND THE MODE OF REPRODUCTION OF AN HERBIVOROUS LADY BEETLE, *HENOSEPILACHNA NIPONICA*. T. Ohgushi, Entomological Laboratory, College of Agriculture, Kyoto University, Kyoto 606, Japan.

I examined between-cohort variations in life time fitness (consisting of immature survival, adult survival, and realized eggs) of a thistle-feeding lady beetle *H. niponica* at the two sites A and F. At site A, early cohorts had higher survival from egg to the reproductive stage than later ones. Whereas, at site F, individuals from mid-cohorts showed higher survival than any other cohorts. Factors that generated this pattern were time-specific operation of arthropod predation and heat stress, which affected primarily the egg and early larval stages. The number of eggs laid by an female was mainly dependent on the reproductive life span, which did not relate to cohorts (i.e., time of adult emergence) at the both of study sites. The cohort differences in life time fitness predict that different reproductive patterns are favored in the two populations: early reproduction at site A while delayed reproduction at site F. The reproductive schedules revealed by the laboratory study strongly support these predictions.

#78

A COMPARISON OF SOME REPRODUCTIVE CHARACTERS OF JAPANESE *ARCHIPINI* MOTHS (LEPIDOPTERA: TORTRICIDAE). Y. Ohira* and T. Oku, Morioka Branch, Fruit Tree Research Station, Morioka, Iwate, 020-01 Japan.

Adults of *Archipini*, species which include 4 uni- and 9 multi-voltine forms, were reared at constant temperatures with supply of water as food. All the species laid eggs in imbricate masses. Within a separate species, the fecundity was positively correlated with the pupal weight. The univoltine species, diapausing as egg or new hatchling had a smaller number of larger-sized eggs and a shorter adult longevity than the multivoltine species, when compared among those of similar body size. This suggests that the univoltine species may allocate a considerable part of maternal stock of nutrition for the prolonged diapause. Among the multivoltine species, the fecundity increased roughly in proportion to the pupal weight, while the individual egg size was larger in medium-weighted species than in heavier and lighter ones. The ratio of total egg weight to body weight was lower in small-sized species than in medium and larger-sized ones, whereas the change in the intrinsic rate of increase was of a reversed pattern. Possible significance of the reproductive diversity is discussed in relation to habitat characteristics, life-cycle pattern, etc.

#79

DIVERSITY OF THE FLY COMMUNITIES (DIPTERA) IN DROPPINGS. L. Papp, Zoological Dept., Hungarian Natural History Museum, Budapest, Hungary H-1088.

Fly samples were collected from horse/donkey droppings in Hungary, Spain, Afghanistan and Mongolia to study species-composition, Shannon-Wiener diversity and evenness. It was found that the droppings have no autochthonous faunas, not even in Europe and the fly community of a given dropping recruits by chance from the imagoes of the species in its vicinity. This statement seems also valid for fly samples reared from cattle droppings on pastures in Hungary. If females of all coprophagous species were of the same fertility, the probability of finding fresh droppings were the same for every fly specimen, and all the populations were of the same mortality, our collecting results would not depend on the number of collected droppings in cases of adequately large samples. Yet we are unable to collect and identify "adequately" large samples: the differences in the sizes of the populations of these species breeding in droppings are as high as 10^4 (10^5). We have to regard "the smallest detectable population size" as 1.

Some methodological problems are also discussed in the conclusion of the paper.

#80

THE ROLE OF THE POTATO, *SOLANUM BERTHAULTII* HAWKES (P1473340) CLONES ON THE FEEDING BEHAVIOR OF THE COLORADO POTATO BEETLE *LEPTINOTARSA DECEMLINEATA* (SAY) (COLEOPTERA, CHRYSOMELIDAE). Y. Pelletier* and Z. Smilowitz, Department of Entomology, Penn State University, University Park, PA 16801 U.S.A.

Feeding of Colorado potato beetle on *Solanum berthaultii* foliage and foliar extracts placed on *S. tuberosum* var. Norchip varied among adult beetles. Females consumed considerably more foliage than males for the overwintering and first generations. Leaf extracts containing trichome B exudates placed on *S. tuberosum* var. Norchip reduced feeding. Considerable variation in feeding was observed among individual Colorado potato beetles. The *S. berthaultii* clone lacking trichome B reduced Colorado potato beetle feeding but extracts placed on *S. tuberosum* var. Norchip had no effect on feeding. The movement of individual Colorado potato beetle adult behavior was quantified in 9 cm diameter plastic cages. Generally, activity of the beetle for the variables studied showed a good degree of variability. Female Colorado potato beetles from the overwintering generation moved less frequently than males from the same generation on the Norchip cultivar. First generation adults were more active than overwintering adults. Beetles moved more frequently on *S. berthaultii* than on Norchip in both generations tested. The *S. berthaultii* clone 1726 (contains both A & B trichomes) promoted the greatest degree of beetle movement in both first and overwintering generations. The beetle had significantly fewer contacts with the foliage of *S. berthaultii* clone 1729 than any of the other treatments.

#81

APOIDEA POLLINATING THE RHODODENDRONS. B. Pieronek, Institute of Biology Pedagogical University of Kraków (Poland) and Institute of Zoology University of Salzburg (Austria)

The results concern Apoidea pollinating *Rhododendron ferrugineum* L. (f) and *Rhododendron hirsutum* L. (h) in the Alps of Austria in 1984, 1985 and 1986. The examined site was the glade Feldereralm above upper forest limit (1600 – 1800 m) within the reach of the national park Hohe Tauern. There were found: *Apis mellifera* L., *Bombus* Latr., *Andrena* L. The average numbers of individuals on 100 sq meters of rhododendrons:

	<i>A. mellifera</i>	<i>Bombus</i> sp.	<i>Andrena</i> sp.	total
1984 f	171	29	1	201
1985 h	75	160	1	236
1986 f	53	25	1	79
1986 h	123	46	1	170

In 1984 and 1986 in pollination of the two rhododendrons the quota of *A. mellifera* was 60–94 %. In 1985 for *Rh. hirsutum* the quota of *Bombus* sp. was 61–74 %. The participation of *Andrena* sp. in all cases was 0–2 %. The percentage of insects pollinating the rhododendrons on 100 sq meters in 1986: Hymenoptera 72.5 (f), 87.6 (h), Diptera 26.9 (f), 11.5 (h), Lepidoptera 0.6 (f), 0.9 (h).

#82

BEHAVIORAL, PHYSIOLOGICAL AND GENETIC VARIABILITY ASSOCIATED WITH MATING TIME IN TABANUS NIGROVITTATUS MACQUART (DIPTERA: TABANIDAE). S.J. Schutz*, R.R. Gaugler, Department of Entomology, Rutgers University, and R.C. Vrijenhoek, Department of Biological Science, Rutgers University, New Brunswick, New Jersey, USA 08903.

Males of the salt marsh greenhead Tabanus nigrovittatus exhibit two distinct daily hovering and mating periods. The timing of each period is associated with a distinct range of ambient temperature and solar radiation. Males collected during the two periods are similar in wing loading, passive cooling rates and wingbeat frequencies but differ significantly in thoracic temperature. Electrophoretic screening indicates that the two groups differ significantly in allelic and genotypic frequencies for Pgm, an enzyme important in mobilization of stored carbohydrates for flight. The two groups may represent isolated populations or physiologically distinct morphs which differ in their thermal requirements for hovering flight.

#83

PARASITOID DIET BREADTH PATTERNS IN THE DOMINANT LEPIDOPTERAN FAUNA OF THE NORTHEAST UNITED STATES William Sheehan, Division of Biological Control, University of California, Berkeley, California 94720, USA.

Following the spread of the gypsy and brown tailed moths in the early part of this century several hundred thousand larvae representing over 300 lepidopteran species were reared for parasitoids between 1915 and 1932 at the Melrose Highlands laboratory. I have analyzed original data summaries for braconid and ichneumonid parasitoid associations with both host and plant species. I tested the hypothesis that plant-specialist herbivores are more likely to be attacked by host- and/or plant-specialist than generalist enemies, and conversely that generalist herbivores are more likely to be attacked by generalist enemies.

#84

EVOLUTION OF ECOMORPHOLOGICAL ADAPTIONS IN THE GENUS BEMBIDION (COLEOPTERA: CARABIDAE). Peter Sowig; Dep.Zoology; Albertstr.21a; D-7800 Freiburg;FRG.

Most of Bembidion-species live exclusively on river banks with no or poor vegetation. Many of them are restricted to a distinct substrate type (mud, clay, silt, sand or gravel). It is noticeable that

1. closely related species of the same subgenus are often coexisting with each other,
2. species with the same habitat requirements have a similar morphology.

Colour and pattern of the elytra, size of the metatrochanter and shape of the pronotum from side view are correlated with the substrate preference of each species. The now arising questions are:

1. how do similar and closely related species coexist?
2. which morphological features are phylogenetically plesiomorph or on which substrate lived the ancestral Bembidion?

From the fact, that related and similar species coexist, one cannot conclude an absence of competition. The uncertainty of the habitat "river-site" is responsible for permanent new colonization of pioneer-species and a competitive situation far from steady state. While species with plesiomorphic characters colonize mud and silt, those with apomorphic features live on an organic substrate. This indicates, that the genus Bembidion evolved to pioneer-species on sterile river sites under competitive conditions.

#85

RELATIONS BETWEEN THE PHYTOCOENOSES AND HETEROPTERA COMMUNITIES. O.Stepanovičová, Department of Zoology, Comenius University, Mlynská dolina B 1, 84215 Bratislava, Czechoslovakia.

Within the years 1960 - 1987 the structure of Heteroptera communities in different habitats of Slovakia /Central Europe/ was investigated. Their coenological evaluation in different natural and anthropogenic habitats /moist meadows, fertile meadows, pastures, cereal monocultures, ruderal communities, xerophile communities, forest-steppes, lowland forests/ showed, that the coenological structure of Heteroptera community is determined by the character of the given phytocoenosis in consequence of the geological, pedological and climatical conditions.

#86

COLONIZATION OF MT. ST. HELENS: THE CARABID COMMUNITY. Patrick Sugg* and J.S. Edwards, Department of Zoology, University of Washington, Seattle WA 98195.

The eruption of Mount St. Helens in 1980 left 600 km² of forestland devastated; the pre-eruption biota was totally destroyed in perhaps 100 km² of that area. Since the eruption, the barren expanse of virgin volcanic surface has been colonized by an assortment of predatory or scavenging arthropods which subsisted on arthropod fallout from myriad dispersing insects and spiders. The majority of these first colonists were carabid beetles, drawn from a variety of different habitats. These source habitats include alpine snowfield edges, montane clearings and river bars. Although disjunct, these habitats have in common the quality of being more or less barren. The success of the carabids in this primary successional landscape has been remarkable. The growth of the incipient community has progressed yearly both in terms of individual species' populations as well as in species diversity.

#87

INTERCLONAL VARIATION IN THE PHOTOPERIODIC RESPONSE FOR SEXUAL MORPH PRODUCTION OF JAPANESE APHIS GOSSYPYII (HOMOPTERA, APHIDIDAE). H.Takada, Laboratory of Entomology, Kyoto Prefectural University, Kyoto, Japan.

The taxonomic status of A. gossypii Glover on a world-wide basis has remained confused. In Japan, Korea and China, gossypii has generally been regarded as a heteroecious and holocyclic full species, although in Europe, gossypii is often treated as an anholocyclic and polyphagous subspecies of the A. frangulae-complex (Thomas, 1968; Stroyan, 1984). A total of 58 clones of A. gossypii, collected from 21 species within 14 families of plants at 13 localities in Japan, were examined to assess interclonal variation in the sexual morph-producing ability. From the response to short photoperiod (10L:14D, 18 °C) the clones examined were classified into 4 life-cycle forms as in the case of Myzus persicae (Blackman, 1971): holocyclic (24 clones), intermediate (4), androcyclic (8) and anholocyclic (22). Some differences were found in the life-cycle form composition even in small samples from different host plants.

#88

REPRODUCTIVE INCOMPATIBILITY BETWEEN THE DIAPAUSING AND NON-DIAPAUSING STRAINS OF THE CITRUS RED MITE, PANONYCHUS CITRI AND ITS ADVERSE EFFECT ON THE DIAPAUSING STRAIN Akio Takafuji, Entomological Laboratory, College of Agriculture, Kyoto University, Kyoto 606, Japan

Two strains of the citrus red mite are known in Japan: one is a diapausing strain (DP) that occurs on deciduous fruit trees and the other is a non-diapausing strain (C) found on both evergreen and deciduous trees. In some pear orchards at intermediate latitudes, the C strain immigrates into pear in early autumn and thus both strains may coexist. Laboratory experiments showed that copulation between the two strains was unrestricted but no adult females were produced from either inter-strain cross. Hatchability of the eggs from the cross between DP females and C males was significantly lower than that from the cross between C females and DP males, or from the inter-strain crosses. A second intra-strain mating was ineffective to a greater extent for the DP females mated with a C male than for the C females mated with a DP male. Field experiments in which both strains together were introduced into pear in early autumn showed that the oviposition rate by DP females was much smaller than that with DP strain only. The results explain the low density of DP, and the low proportion of females from overwintered DP eggs in a pear orchard in which both strains coexisted in the previous autumn.

#89

DIAPAUSE AND WING DIMORPHISM IN A TROPICAL SEED BUG (RHOPALIDAE: HEMIPTERA). S. Tanaka*, H. Wolda and D.L. Denlinger, Smithsonian Tropical Research Institute, 2072 Balboa, Panama and Department of Entomology, Ohio State University, Columbus, Ohio, 43210, USA.

Jadera aeola reproduces in enormous numbers on seeds of Sapindaceae that have dropped to the forest floor late in the dry season on Barro Colorado Island (9°N), Panama. We explored the possible involvement of imaginal diapause in this species as a strategy to survive the seasons when the food resource was scarce.

We found that newly emerged long-winged adults entered diapause and environmental conditions such as food and mating, but not photoperiod, influenced diapause regulation. The diapause appears to be JH regulated.

Short-winged forms (a small portion of the first generation) failed to enter diapause and produced a second generation. Under natural photothermal conditions, short-winged females started ovipositing earlier, produced more but smaller eggs, and died earlier than long-winged forms. Wing dimorphism of this species could be a response to unpredictable availability of the food resource determined by seed production of the host plants (Sapindaceae) and by the timing of the onset of a wet season.

#90

RELATION BETWEEN HARDNESS OF NEW LEAF AND DENSITY OF SCRITOTHRIPS DORSALIS HOOD (THYSANOPTERA: THRIPIDAE) IN SATSUMA MANDARIN GROVE. A. Tatara and K. Fruhashi, Shizuoka pref. Citrus exp. Stn., Shimizu, 424, Japan.

It is well-known that S. dorsalis is an injury to soft leaf of their host plants. The hardness of Satsuma mandarin new leaves infested with larva and adult of S. dorsalis were measured by Reo meter respectively. Its range infested with adult was very narrow and was biased soft. It is considered that soft leaf is suitable for adult to oviposit. The range infested with larva was wide. The hardness of leaf in summer became possible to feed for larva at 10 days after sprouting and impossible to feed at 30 days after. This period to be possible to feed for larva was enough to develop from egg to adult for S. dorsalis in summer. Therefore it is considered the larvae on leaf can hardly move to other leaf. The trend in the number of favorite leaves for S. dorsalis larvae and the trend in S. dorsalis density on leaf in Satsuma mandarin grove were resemble each other and there is close relation between them.

#91

GROWTH AND DEVELOPMENT IN THE PHANTOM MIDGE, CHAOBORUS AMERICANUS (DIPTERA: CHAOBORIDAE). J.A. Traina and C.N. von Ende*, Department of Biological Sciences, Northern Illinois University, DeKalb, Illinois 60115-2861, USA.

A morphologically based developmental polymorphism has been described for 4th instar larvae of Chaoborus americanus (Bradshaw 1973). Our laboratory experiments with overwintering larvae from Tender Bog Lake (Upper Peninsula, Michigan) corroborated that small, pale 4th instar larvae (SPL) pupated later than large, yellow 4th instar larvae (LYL) when exposed to high temperature (20°C), long day (16L:8D), and high food conditions. However, SPL pupal weights were $\geq$ LYL pupal weights. This suggests 4th instar size differences are due to larvae being at different stages of growth within the instar. Census data suggests the population has a 2-year generation time with larvae spending 2 winters as a 4th instar. Therefore, LYL and SPL appear to be from different generations, with growth from SPL to LYL occurring during the second summer. Our laboratory growth experiments have shown C. americanus larvae do not have obligate diapause. Data from Redfield Pond (northeastern Illinois) indicate a similar size distribution of larvae could occur in a multivoltine population due to the overlap of generations produced within a single year, or asynchronous oviposition.

#92

THE INFLUENCE OF NaCl, KCl AND MgSO₄ SOLUTIONS ON GROWTH AND DEVELOPMENT OF CULEX THEILERI THEOBALD (DIPTERA: CULICIDAE). T.C. de K. van der Linde*, P.H. Hewitt and M.C. van der Westhuizen, Department of Zoology and Entomology, University of the Orange Free State, Bloemfontein 9300, Republic of South Africa.

Blood-fed Culex theileri Theobald females were allowed to oviposit on a series of NaCl, KCl and MgSO₄ solutions ranging from 0,0 M (distilled water) to 0,20 M. In both NaCl and KCl there was a preference for the 0,02 M and 0,04 M solutions, with a marked decrease in number of egg rafts with increase in molarity of the solutions. The MgSO₄ solutions yielded a higher percentage of egg rafts, with no significant differences between the various molarities. The hatching percentage in all three salt series up to 0,12 M was above 70% with a rapid decrease at the higher molarities.

The development of the immature stages was the most successful in NaCl-solutions with adulthood being reached in up to 0,16 M solutions. In KCl-solutions development was less successful with adults occurring only in solutions up to 0,08 M. However, in MgSO₄ adulthood was only reached in solutions up to 0,01 M. Above this molarity all the larvae died before completion of the larval stages.

These results are compared and discussed with results from the field.

#93

MULTIPLE MATINGS INCREASE THE FECUNDITY OF THE YELLOW SWALLOWTAIL BUTTERFLY, PAPILIO XUTHUS L. M. Watanabe, Department of Biology, Faculty of Education, Mie University, Tsu, Japan 514.

Females of the yellow swallowtail butterfly were reared in the laboratory. They were divided into four groups held under different mating conditions: nonmating (virgin) and mated once, twice, and three times. The number of eggs in the ovaries was counted by dissection. Virgin females produced increasing numbers of mature eggs, up to about 30, in the week following emergence. When the female had mated once, the number of mature eggs was significantly higher than that of virgin females by the second day after emergence. However, the double- and triple-mated females did not increase the number of eggs in each state further than the single-mated females. The double-mated females deposited significantly more eggs than the single-mated females in the laboratory. The triple-mated females also deposited more eggs on the day after the third mating than the double-mated females. Thus, multiple matings increased the number of eggs deposited. The change in the hatchability and the morphology of the spermatophore in the bursa copulatrix suggested that the sperm from the last mating had precedence.

#94

WASH-AWAY: FLOODS AND THE DISTRIBUTION OF SAWFLIES AND PARASITIDS ON WILLOWS IN OAK CREEK CANYON. R.L. Woodman (Northern Arizona University, Flagstaff, Arizona, USA).

Herbivores that attack plants in drainages subject to floods may be at risk of drowning or being swept away. Distribution patterns of herbivores on these plants should thus reflect flood impact by scarcity or low abundance of herbivores in the more heavily swept plants. The results of extensive censuses in 1987 of *Pontania* and *Phyllocolpa* (Hymenoptera: Tenthredinidae) galls on Arroyo Willow (*Salix lasiolepis*) in Oak Creek Canyon indicate that heavily flood-swept midstream willows carry fewer galls than do un-swept up-bank plants. Likewise, parasitism levels were lower in gall populations on midstream willows. Experimental caging of sawfly cocoons (10 cocoons per cage, 1 cage per plant) basally under 6 midstream and 6 up-bank willows indicated that cocoons cannot survive through spring floods under midstream plants. Marked piles of small stones were placed under 3 midstream and 3 up-bank plants to assess litter stability. All midstream piles were scattered, while up-bank piles remained intact after flooding, suggesting that litter has little chance of remaining under the midstream willows. These results suggest that, as both gallers and parasitoids overwinter in the litter, flood removal of litter may be a viable explanation for the observed distribution patterns of galls and parasitism in this system.

#95

SOIL MICROARTHROPODS AND VESICULAR-ARBUSCULAR MYCORRHIZAL FUNGI: INTERACTIONS AFFECTING PLANT GROWTH AND NUTRIENT UPTAKE. E. Zaborski* and S.B. Hill, Department of Entomology, Macdonald College of McGill University, Ste. Anne-de-Bellevue, Quebec, Canada H9X 1C0.

Soil microarthropods may sustain plant growth through their indirect stimulation of decomposition and nutrient cycling, but they may also reduce plant growth by feeding on root tissue or root symbionts. Although grazing by *Folsomia candida* (Collembola: Isotomidae) has been shown to decrease the growth response of plants to vesicular-arbuscular mycorrhizal (VAM) infection in pots, response to a more complex microarthropod community remains undemonstrated.

VAM-inoculated and uninoculated onions were grown in 750ml pots of low-phosphorus clay soil to which the following treatments had been applied: no treatment (native microarthropod population); heated gently (40°C, 24h) to kill microarthropods; and 100 *F. candida* introduced after heating. Pots were harvested after 6 and 12 weeks, and dry mass production, shoot P content, VAM colonization and microarthropods were quantified.

Dry mass production increased significantly in response to VAM inoculation, but partitioning between shoots and roots, as well as the magnitude of the response, was influenced by soil treatment.

#96

COMPARATIVE GROWTH PATTERNS IN DIFFERENT KINDS OF GALLS. S.P. Goyal, Department of Botany, University of Rajasthan, Jaipur, India.

This paper considers the differences in the comparative growth patterns of *Phylloxera* galls and normal grape stem single cell clones, with the growth patterns of flower and stem galls. Statistical investigations reveal that: (i) the presence of RNA or DNA in the medium enhances growth in terms of cell/nucleus and nucleus/nucleoli ratios; (ii) the cumulative ratio graphs of cell/nucleus and nucleus/nucleoli are fairly parabolic; and (iii) the indefinite existence, under hydrostatic equilibrium, of air spaces between hypertrophied and non-hypertrophied parts. Correlation coefficients show the growth relationships in the different parts.

APPARENCY AND THE EVOLUTION OF DEFENSE: A NEW SYNTHESIS. L.J. Orsak, Scientific Methods, Inc., P.O. Box 599, Durham, CA 95938.

Apparency (= the probability of being detected by predators) is a composite feature influenced by numerous factors including: body color, size, and shape, longevity, polymorphism, behavior, intraspecific spacing, and predator and habitat factors. The concept of apparency facilitates our understanding of animal defensive strategies and provides insights into the evolution of defensive ensembles.

THE CHEMICAL DEFENSE CORNUCOPIA: FACTORS AFFECTING ITS EVOLUTION. M. S. Blum, Department of Entomology, University of Georgia, 30602 U.S.A.

The significance of apparency in the evolution of chemical defenses, specific defensive compounds, and delivery systems will be analyzed in terms of the sources of apparency that have affected the evolutionary expression of both environmental frequencies and countermeasures to specific predator classes. The oözes, and emetic compounds will be discussed as a possible function of either taxonomic constraints or effectiveness as repellents against specific predators in selected microhabitats. Ultimately the chemical defenses of arthropods will be analyzed as major forces that have permitted these invertebrates to exploit disparately hostile environments with great success.

THE EVOLUTIONARY COSTS OF DEFENSIVE MECHANISMS AND STRATEGIES. J.M. Pasteels, Laboratoire de Biologie Animale et Cellulaire, Université Libre de Bruxelles; 50, Av.F.D. Roosevelt, 1050 Bruxelles, Belgium.

Chemical defense, as other defensive mechanisms, is part and parcel of a life cycle strategy and in social insects of social organization. Hence, trying to compare the intrinsic merits of chemical defense to those behaviorally, physiologically, and/or morphologically mediated defenses in terms of cost-benefit for say defence alone without considering the other life cycle parameters, is probably not a meaningful approach. In insects, defensive strategy can shift over the course of evolution from chemical to mechanical and behavioral, or vice versa. This will be illustrated by selected examples from leaf beetles and termites.

However, it is useful to compare the differential cost of defence within one specific defensive strategy (e.g. chemical defence), wherein different modalities are employed (e.g. sequestration versus *de novo* synthesis). The measure of total metabolic cost of chemical defence seems possible in termites, in which it is equivalent to the cost of producing soldiers. This cost can be extraordinarily high. In leaf beetles, no direct measure of metabolic cost is yet possible; that it is costly, is suggested by the use in some species of plant-derived compounds in place of *de novo* synthesized chemicals. The possible advantages of using plant-derived compounds in terms of increasing efficiency and decreasing costs will be discussed. It is stressed, however, that sequestration has its own cost and can replace *de novo* synthesis in only rare favourable circumstances.

STRATEGIES AND SUBTLETIES IN THE EVOLUTION OF MIMICRY IN SOME BUTTERFLIES. A.P. Platt, Department of Biological Sciences, U.M.B.C., Catonsville, Maryland 21228.

In its simplest form, mimicry evolves through directional selection towards superficial resemblances of "biotic substrates" (unpalatable models), in the same ways that cryptic patterns arise on non-living (or inanimate) backgrounds, such as green vegetation, dead leaves, or tree bark. Among mimetic species, phenotypic fixation for the closest approximation of the model's appearance usually occurs. Differential predation rates drive the selective modifications underlying mimicry. Non-mimetic species in time produce Batesian relationships, involving conspicuous unpalatable models and palatable mimics. These, in turn, may eventually give rise to the extensive unpalatable Müllerian complexes, such as the well-known ones of the neotropics, Asia, and Africa. The evolution of mimetic forms can take place either at the intraspecific level (between forms, races, or subspecies), or between species, within a single clade. If counter-balancing selective forces are strong enough across clines, phenotypic divergence can occur despite nearly free gene flow between adjacent populations. Many of the subtleties of mimetic evolution are found among the species and forms of the monophyletic New World admiral butterflies (*Limenitis*: Nymphalidae). The biogeographic, selective, and genetic aspects of mimetic evolution will be discussed in this genus, using experimental hybridization as a basic investigative approach.

EVOLUTIONARY PATHWAYS: INVOLVEMENT OF INDIVIDUAL, KIN, AND GROUP SELECTION IN THE EVOLUTION OF DEFENSE. T. Guilford, Dept. Zoology, University of Oxford, Oxford, U.K. OX1 3PS

Controversy surrounds the question of the involvement individual, kin, and group selection in the evolution of aposematism. Though some argument is definitional (I treat this briefly), much is not. I discuss a common fallacy that individual is more parsimonious than kin selection. I show where kin selection is invoked wrongly, by emphasizing the evolutionary importance of (a) family grouping effects on initial viability of traits with density-dependent benefits, and (b) another selective pathway involving "green beard" (or "synergistic") effects. I next explore how the contribution of each evolutionary pathway is affected by the precise defensive mechanism involved. I discuss the importance of (a) prey apparency, (b) predator psychology, (c) defensive mechanism, and (d) warning signal modality, in altering this contribution.

THE CONSTRAINTS ON PROTECTIVE BEHAVIOR: LINES OF DEFENSE, SIZE, ECTOTHERMY, AND HABITAT. D.L. Evans, Beaver Brook Reservation, MDC, 66 Mill St., Belmont, MA 02178, USA.

Defensive behavior can be discussed according to contact levels: i.e. a continuum from a time before the prey is perceived to when it is observed to the point of contact, etc. The particular ensemble of defensive behavior which has evolved depends greatly upon other life variables such as size, thermoregulatory techniques, aspect constancy, and territoriality to name a few items. For example, there is abundant evidence that demonstrates the clear constraints of gross body size on specialization in crypsis, flight, and thermoregulation. In this paper, I will synthesize and present the several paradigms which have been developed over the past decade of research on defensive behavior.

THE EVOLUTION OF LINKED DEFENSES: DISTASTEFULNESS, APOSEMATISM, AND AGGREGATION. B. Sillén-Tullberg, Department of Zoology, University of Stockholm, S-10691 Stockholm, Sweden.

Many insect species form exposed aggregations either as larvae or adults, but the adaptive value with gregariousness is poorly understood. The fact that gregarious species are often warningly colored has been taken as evidence that kin selection is important for the evolution of both distastefulness and aposematism. Gregariousness has also been regarded as a way to increase the aposematic signal. However, many aggregations do not consist of closely related individuals, and most aposematic species live solitarily. Why then do insects aggregate, or rather, which factors determine whether a species is solitary or gregarious? I will here show that, from a predation point of view, distastefulness is an important pre-requisite for the evolution of gregariousness, and that gregariousness may evolve without giving an increased aposematic effect. I will also show that the evolution of both distastefulness and aposematic coloration generally precede that of gregariousness.

NOCTURNAL PREDATION AND THE EVOLUTION OF ARTHROPOD DEFENSES D.W. Whitman, IBPMRL USDA, Tifton, GA, 31793, USA.

Both diurnal and nocturnal predators have influenced the evolution of arthropod defenses, but in different ways. This is because nocturnal and diurnal predators often use different sensory modalities to locate and identify their prey; a phenomenon to which arthropods have responded. As a result, defense ensembles of arthropods from diverse taxa correlate with their diurnal activity patterns.

HOW AQUATIC ENVIRONMENTS UNIQUELY MOLD ARTHROPOD DEFENSES. R.B. Aiken*, Department of Biology, Mount Allison University, Sackville, New Brunswick, Canada E0A 3C0 and P. Adler Department of Entomology, Clemson University, Clemson, South Carolina, U.S.A. 29634-0365.

Arthropods that live in aquatic environments are exposed to a very different set of selective forces in the ways they defend themselves from predators, parasites and conspecifics than are their terrestrial counterparts.

In this paper, we will take a comparative approach in examining defensive mechanisms in lentic and lotic water contrasting them with corresponding mechanisms in terrestrial and marine forms. Mechanisms will be divided into primary (those that operate without an immediate threat) and secondary (those that function in response to a threat). By drawing on published evidence on environmental constraints, the influence of predators and parasites and the taxonomic distribution of various defense mechanisms, we will highlight general trends and common threads in the evolution of such mechanisms in aquatic arthropods.

ASPECTS OF THE EVOLUTION OF ARTHROPOD DEFENCES IN TROPICAL ENVIRONMENTS.

Keith S. Brown Jr., Laboratório de Ecologia Química, Departamento de Zoologia, Instituto de Biologia, UNICAMP, C.P.6109, Campinas, São Paulo, Brazil 13081.

The intense and continuous biotic pressure on arthropods in tropical environments leads to notable and widespread adaptive syndromes such as mimicry and chemical defence, accompanied by widely accepted mythologies. Long-term observations, experiments and chemical analyses on aposematic Neotropical butterflies have suggested some patterns not consistent with this "common wisdom." Complex genetic control of mimetic color-patterns can in some environments favor adaptive mimetic polymorphism in Müllerian mimics. A multiplicity of mimetic color-patterns (at least 12 basically divergent rings in most localities) may well be selected for a dual function, combining generalized background matching (a non-signal) with a warning signal at close range. Obtention of adult defensive chemicals from the larval hostplant as in the classic case of the Monarch (*Danainae*) seems to typify primitive groups (Troidine swallowtails, Pierinae, the Lycaenid *Eumaeus*). Adult seeking of defensive dehydropyrrolizidine alkaloids (PAs) characterizes almost all *Danainae* and *Ithomiinae*. The most advanced groups, like the *Heliconiini*, biosynthesize their own cyanogenic glycosides, in spite of having them available in the larval foodplants. *Acraeinae* also synthesize in all stages their own cyanogen, not storing the abundant PA continuously ingested from both larval and adult foodplants.

CRYPISIS IN A CHANGING ENVIRONMENT: THE BACKGROUND MATCHING COLOR SYSTEM OF TIGER BEETLES (COLEOPTERA: CICINDELIDAE). T.D. Schultz, Div. of Entomology, Peabody Museum of Natural History, Yale University, New Haven, CT, USA 06511.

Tiger beetles of the genus *Cicindela* produce cryptic color patterns through the spatial fusion of structural colors that mix and resemble the colors of soils and backgrounds. Through minor changes in cuticle ultrastructure, this chromatic system has permitted the evolution of diverse color patterns that match various backgrounds of different colors and grain. In some species, color variation can be correlated with soil or background differences using an adaptation of Endler's approach for quantifying background matching. Matching strategies vary with habitat and microhabitat structure. Color polymorphisms may arise and be maintained in environments where backgrounds change in time and space.

CONSISTENCY OF DEFENCES IN TAXONOMIC GROUPS: A REFLECTION OF PHYLOGENY AND ECOLOGY. Malcolm Edmunds*, School of Applied Biology, Lancashire Polytechnic, Preston, Lancs., PR1 2TQ, U.K., and Janet Edmunds, Mill House, Goosnargh, Preston, Lancs., PR3 2JX, U.K.

Reasons why the various insect orders have different ways of avoiding being preyed on are discussed. It is shown that the diagnostic features of many successful orders increase an insect's chances of avoiding being eaten. The defensive repertoire of insects may be limited by phylogeny, ontogeny, feeding habits, other defences, and, to a lesser extent, by ecology and reproduction. A way of escaping from some of these limitations is holometabolous development: metamorphosis allows larvae and adults to adapt and evolve in different ways and so increases plasticity of defences.

THE EVOLUTIONARY APPEARANCE OF DEFENSE IN LEPIDOPTERA. J.E. Rawlins, Section of Invertebrate Zoology, Carnegie Museum of Natural History, 4400 Forbes Avenue, Pittsburgh, Pennsylvania, United States of America 15213.

The evolutionary appearance of an adaptation for defense in a lineage is often associated with subsequent modification in macroevolutionary patterns of divergence and diversity in the defended line. Using both classic and novel examples from monophyletic taxa of Lepidoptera, patterns of evolutionary constraint between defense mechanisms and other characters are quantified. Comparative analysis of species diversity between defended and undefended sister lineages characterizes the impact of defenses on subsequent radiation.

Relatively static processes implied by significant correlations between defense adaptations and subsequent diversity or divergence of defended lines provide explanations of major evolutionary trends for many lineages of Lepidoptera. For other lineages, macroevolutionary "escape" from constraints imposed by defense mechanisms appears likely, perhaps by loss of defenses, new predator lineages, or further novelties (predator or prey) altering apparency.

DIRECT AND INDIRECT EVIDENCE ON THE MODUS OPERANDI OF CHEMICAL DEFENSE IN THE MONARCH BUTTERFLY, DANAUS PLEXIPPUS L. (LEPIDOPTERA: NYMPHALIDAE). L.P. Brower, Department of Zoology, University of Florida, Gainesville, Florida, U.S.A. 32611.

Chemical defense in the monarch butterfly is dynamic and is based upon cardiac glycosides derived from their larval foodplants of the milkweed genus Asclepias. The bitter and emetic characteristics of these substances are effective deterrents to some (but not all) known and potential bird and mouse predators, and the degree of protection they confer varies in place and time. Deployment of the defensive chemicals is multifaceted in the life history stages. The monarch's enormous overwintering aggregations in central Mexico and along the California coastline appear possible because of this chemical defense strategy, albeit imperfect. Recent evidence indicates that the various migrant generations of the monarch have very different degrees of cardenolide protection. Adult-obtained pyrrolizidine alkaloids, and pyrazine compounds, may also play protective roles either independently or through synergistic effects with the cardiac glycosides.

OUT ON THE EVOLUTIONARY LIMB: EXTREMISM IN DEFENSE. J.O. Schmidt, Southwestern Biological Institute, W. Brichta Dr., Tucson, AZ 85745, U.S.A.

Extremism in defensive contexts is defined as the possession of the most derived or extreme form or expression of any type of defensive element. Extremism as the pinnacle of development of any defensive adaptation confers anti-predator benefit to the possessor, but also entails costs. Examples of defensive extremists selected from among the Hymenoptera include: the Mutillidae, whose sting (aculeus) is longer and more mobile than that of any other aculeate Hymenoptera; Pogonomyrmex, harvester ants that possess the most lethal known arthropod venom (to mice); Paraponera clavata, a large neotropical ant species whose sting is more painful to humans than that of any other hymenopteran; Apis, highly eusocial bees whose sting apparatus autotomizes more readily than that of any other hymenopteran; Pepsis, large spider wasps whose stings induce the most intense, immediate pain in humans of any stinging insects; and Crematogaster, ants whose sting apparatus is completely modified into a flexible applicator for delivering topical allomones. Extremism in defensive expression is analyzed in terms of its actual value in defense, its relationship to the apparency (= conspicuousness) of the extreme species to their predators, and its evolution.

WHAT IS THE ADAPTIVE SIGNIFICANCE OF MULTICOMPONENT DEFENSIVE REPERTOIRES? D.L. Pearson, Department of Biology, Pennsylvania State University, University Park, Pennsylvania, USA, 16802.

Most insects exhibit a combination of anti-predator mechanisms that can include morphological (aposematic, camouflage, spines), behavioral (nocturnal activity, conspicuous displays), and physiological (chemicals) characters. For some species these multiple anti-predator mechanisms are apparently effective only in combination; for other species they may serve as a series of "lines of defense", each brought into play at certain levels of danger; for yet other species separate defenses may each be directed against different types of predators. Although these three alternatives need not be mutually exclusive, future tests may distinguish different situations under which each predominates.

Compounding these complex explanations for multiple anti-predator mechanisms are alternative and simultaneous functions of these same mechanisms in sexual selection, competition, adaptation to abiotic factors, as well as delayed effects of historical changes in predator types. Future tests must eventually be designed to incorporate all these factors.

Reproductive Isolation And Signal Specificity In Insects: Adaptive Or Incidental?

REPRODUCTIVE ISOLATION: FUNCTION OR EFFECT? H.E.H. Paterson, Department of Entomology, University of Queensland, St Lucia, 4067. Australia.

The way we conceive species determines our understanding of how they can arise de novo. In other words, if we are to understand how species evolve we need to identify the role of natural selection in the process.

Under the Biological Species Concept, species are conceived in terms of the action of isolating mechanisms. In assessing the validity of the concept, it is crucial to ask whether isolating mechanisms have evolved in order to isolate a gene pool or not.

SEXUAL AND SOCIAL SELECTION AND THE SPECIES-SPECIFICITY OF INSECT SIGNALS. M.J. West-Eberhard and W.G. Eberhard*, Smithsonian Tropical Research Institute and Escuela de Biología, Universidad de Costa Rica, Costa Rica.

Social selection theory predicts species-specificity of signals used in competition for mates and for other resources. The theory is also consistent with many other patterns in the evolution of such characters, including their intraspecific variation, complexity, simplification in monogynous species, greater development in the more sexually competitive sex, and failure to often show character displacement. Alternative explanations of signal specificity (e.g., as a product of selection for pre-mating reproductive isolation or fertilization efficiency) have so far proven less broadly applicable. Under sexual selection theory the species specificity of insect signals can be regarded as both incidental and (secondarily) adaptive: it can be the incidental result of rapid evolution of traits primarily adaptive in mating competition; and it may sometimes be secondarily adaptive (pre-adaptive) in preventing deleterious hybridization of divergent forms.

THE EVOLUTION OF REPRODUCTIVE ISOLATION AS AN ADAPTIVE RESPONSE TO SEXUAL SELECTION. P. L. Phelan, Department of Entomology, The Ohio State University, OARDC, Wooster, Ohio, 44691, USA.

Central to our understanding of the species concept is knowledge of the nature and evolution of reproductive isolating mechanisms. The once widely held model of Dobzhansky, which propounds that sexual isolation principally evolves through a selection against hybrids of differentially adapted populations due to their lower fitness, has more recently lost support due to both theoretical difficulties and the paucity of examples of the pattern of character displacement predicted by the model. These problems have been cited as evidence for the alternative model of Muller, whereby sexual isolation is viewed simply as an incidental by-product of divergent adaptation between populations; however, an adaptive response model not given consideration is that of Fisher, who suggested that interspecific sexual challenge could trigger a runaway sexual selection event that might cause the selected trait to spread outside the zone of interspecific overlap. Surveys of species-specific courtship characters, especially among the Lepidoptera but also including other groups, suggest a pattern more consistent with Fisher's predictions than with either reproductive character displacement or the predictions of the incidental models.

REPRODUCTIVE ISOLATION BY MEANS OF FEMALE SEX PHEROMONES: ADAPTIVE OR INCIDENTAL? Mart C.M. De Jong* & Wim M. Herrebut, dept. of Population Biology, Univ. of Leiden, P.O.Box 9516, 2300 RA Leiden, The Netherlands.

Viable and fertile hybrids between the species of the genus *Yponomeuta* have been reported from laboratory experiments. Hybrids were, however, never found by the allozyme analysis of field samples. This reproductive isolation between these species is largely caused by female sex pheromones.

As an example we considered two species of the genus, which are closely related and occur in large numbers at the same site, at the same time. The question was whether the apparent reproductive isolation between the two species is adaptive or incidental. Theoretical considerations and experimental work show that males are probably not selected to avoid matings with other species but rather only to maximize their intra-specific mating success. Females on the other hand could well have been subject to inter-specific selection, and therefore be the adaptive cause of reproductive isolation.

THE IMPORTANCE OF SEX PHEROMONES IN THE EVOLUTION OF REPRODUCTIVE ISOLATION IN SMALL ERMINE MOTHS. Christer Löfstedt*, Department of Ecology, Lund University, Helgonav. 5, S-223 62 Lund, Sweden, Wim Herrebut, Division of Systematics and Evolutionary Biology, University of Leiden, The Netherlands, and Steph Menken, Hugo de Vries Laboratory, Amsterdam, The Netherlands.

Sex pheromone communication in the nine European forms of small ermine moths *Yponomeuta* spp is reviewed in regard to the phylogeny of the species.

Biosynthetic pathways to the pheromone components are proposed on the basis of fatty acid pheromone precursors found in the pheromone glands and a phylogenetic tree for the genus is constructed based on isoenzyme analyses. Six of the ermine moths use a mixture of (E)-11- and (Z)-11-tetradecenyl acetate in different ratios as primary pheromone components, with combinations of tetradecyl acetate, (Z)-11-hexadecenyl acetate and the corresponding alcohols of the acetates as additional components. The pheromone differences among these species might have evolved as *character displacement* in the sex communication channel upon secondary contact between populations that have already diverged genetically. It is suggested that the plesiomorphic ermine moth pheromone is a mixture of (Z)-11- and (E)-11-tetradecenyl acetate and the corresponding alcohols. The remaining three species have pheromones that differ more radically. A common denominator of these species seems to be that they have lost some of the pheromone components of their ancestors. In this case *quantum changes* in the pheromone composition might have been the event triggering divergence of two populations. The importance of sex pheromones in the evolution of reproductive isolation in small ermine moths is discussed in relation to host plant shifts.

ETHOLOGICAL ISOLATION IN A SOLDIER BEETLE HYBRID ZONE. D.K. McLain, Department of Biology, Landrum Box 8042, Georgia Southern College, Statesboro, Georgia 30460, USA.

This report examines ethological isolation in a zone of secondary contact between elytral spot morphs of the soldier beetle, *Chauliognathus pennsylvanicus* DeGeer. Spot lengths are always short in northern Georgia, short to long in north-central Georgia, and only long in central to south Georgia. In the zone of overlap between short and long spots positive assortative mating by spot length is significant only in the northern part of the zone, and then only where beetle density is low. Where assortative mating is not significant, individuals may still express spot preferences, but the spot length of the chooser and its mate may differ. Within the zone of secondary contact, assortative mating may reflect the maintenance of species barriers which have eroded elsewhere in the zone or the establishment of new barriers (reinforcement). Ethological isolation tests suggest the latter since beetles from outside the zone do not discriminate on the basis of spot length as strongly as beetles within the zone. High population densities in the middle to southern part of the zone may inhibit the exercise of certain aspects of mate choice.

CALLING SONG AND REPRODUCTIVE ISOLATION IN THE KATYDID *Mygalopsis marki*. I. R. Dadour, Zoology Department, The University of Western Australia, Nedlands, Western Australia, 6009.

The katydid *M. marki* has genetically distinct northern and southern populations which are connected by a hybrid zone. Northern populations are fixed for a phosphoglucomutase (PGM^b) allele (sex-linked) and possess a leucylglycylglycine peptidase (LGGP^d) allele (autosomal) at moderate frequencies, whereas the southern populations are fixed for PGM^a and lack LGGP^d. The hybrid zone was indicated by two populations polymorphic for PGM, with the genotypic frequencies for both PGM (in females) and LGGP conforming closely with Hardy-Weinberg expectations. The number of teeth on the stridulatory file, the sound generating mechanism in katydids, was also measured, with northern populations having lower mean numbers of teeth than southern populations. From the implication that random mating is occurring in the hybrid zone, it seems that song is not important as a pre-zygotic isolating mechanism. However, I show that there are calling song differences (temporal pattern) between northern and southern populations.

MALE SONG, FEMALE PREFERENCE AND ASSORTATIVE MATING IN A GRASSHOPPER HYBRID ZONE. R.K. Butlin* and M.G. Ritchie, Department of Zoology, University College, Cardiff CF1 1XL, U.K., and School of Biological Science, University of East Anglia, Norwich NR4 7TJ, U.K.

Two subspecies of the grasshopper, *Chorthippus parallelus*, meet and form a hybrid zone in the Pyrenees. The subspecies differ in morphological, behavioural, chromosomal and electrophoretic characters. F1 hybrid males are sterile but females are fertile.

In transects across the zone several male song characters change in a simple clinal pattern, but with differing cline widths. Assortative mating between populations from opposite sides of the zone declines as the zone centre is approached. However, female preference for parental males is apparently more divergent close to the zone than distant from it on either side.

These observations are discussed in the context of the reinforcement model of speciation. We consider that the model has little firm support either in this case or in general.

SPECIATION AND SIGNAL DIFFERENTIATION. Daniel Otte, The Academy of Natural Sciences of Philadelphia, 19th and The Parkway, Logan Square, Philadelphia, Pennsylvania 19103, USA.

Most species-specific signal differences in Orthoptera arise from coevolution among species; they are probably rarely due to pleiotropy, or a result of intraspecific sexual selection. The course of evolution depends on the species mix, and precision in coadaptation depends on whether selection is persistent (as in forests) or variable (as in grasslands). Speed of signal differentiation and rate of speciation depends on population breeding structure, which in turn depends on certain aspects of environmental heterogeneity. The results of character displacement are everywhere, even if its signs are short-lived.

SIGNAL SPECIFICITY IN WOLF SPIDERS (ARANEAE: LYCOSIDAE): A COMPARISON OF CLOSELY RELATED SPECIES. G.E. Stratton*, Albion College, Albion, MI 49224 and G.W. Uetz, Univ. of Cincinnati, Cincinnati, OH. 25221.

The acoustic signals produced by courting males in the *Schizocosa ocreata* species group were analysed and compared using digitized sonographs. There is strong species specificity in the courtship songs of this group, with the behavior correlating closely with the presence or absence of male secondary sexual characteristics. Several new etho-species (as judged by reproductive isolation) have been recognized in this species-group. Species with conspicuous bristles on the first pair of legs use these legs extensively during courtship (*S. ocreata* and *S. crassipes*). In *S. ocreata* these leg moves are visual signals that are important for successful communication (Scheffer unpublished thesis). The courtship behavior in the species with dark legs lacking the bristles was typically much less visually conspicuous, and consisted of stridulation (*S. stridulans* and *S. floridana*). The one species that lacked both bristles and pigmentation (*S. rovneri*) displayed a courtship behavior that produced very loud sounds. This species relies on vibrational cues for species recognition. The strong correlation between secondary sexual characteristics and courtship signals suggests that these characters have been selected for by sexual selection.

SPECIATION IN COMMON *CHRYSOPERLA* GREEN LACEWINGS (NEUROPTERA: CHRYSOPIDAE): ARE SONG DIFFERENCES ENOUGH? C. S. Henry, Department of Ecology and Evolutionary Biology, Box U-43, University of Connecticut, Storrs, Connecticut, USA 06268

The widespread North American green lacewing species *Chrysoperla plorabunda* and *Ch. downesi* are not, in fact, true biological species, but instead comprise a complex of at least six sibling, cryptic species. Each member of the complex remains isolated from other, often sympatric, sister taxa because of species-specific courtship songs, produced by both males and females in a precise duet. Songs are quite invariant over the extensive geographical ranges of each "acoustical species." Recent work suggests that even seemingly well-defined species or subspecies of *Chrysoperla* are actually just odd pieces of much more broadly distributed song species. *Ch. mohave* for example, is in fact part of *Ch. downesi*, although it is ecologically and physically more like *Ch. plorabunda* and has long been considered a subspecies of the latter taxon. Some evidence for the reinforcement of premating isolation can be found when one compares songs within sympatric vs. allopatric populations of *Chrysoperla* and the closely related genus *Chrysopiella*. In these cases, I consider sexual selection to be the principal mechanism behind the reinforcement of species isolation, rather than an alternative hypothesis explaining song differences.

Morphology Of Male Competition In Insects: Intrasexual Selection And Secondary Sexual Characteristics

THE EVOLUTIONARY SIGNIFICANCE OF MALE DIMORPHISM AND ALTERNATE BEHAVIOURAL STRATEGIES IN *ONTHOPHAGUS BINODIS* THUNBERG (COLEOPTERA: SCARABAEIDAE). D.F. Cook, Department of Zoology, University of Western Australia, Nedlands 6009, Western Australia.

Male dimorphism in the development of cephalic and thoracic horns occurs frequently in dung beetles. A morphometric analysis revealed structural dimorphism within *O. binodis* males, separating horned males, females and hornless males. *O. binodis* adults are found in dense aggregations, where within a single aggregation there is considerable size variation. Intense competition for females has probably resulted in the evolution of male dimorphism. Hornless males may be a facultative adaptation to reduce competition with large horned males.

Female *O. binodis* provisioned more eggs when reproducing with horned males compared with hornless males, regardless of the male's body size. Only horned males invest in helping their mate provision eggs. Horned males also guard their mate's burrow during cooperative behaviour, probably to protect the male's ejaculate because of a high potential for sperm displacement. Hornless males are the predominant morph in natural populations, and being presumably less successful in male-male competition, are predicted to adopt alternate routes to reproduction. Adult size and morph is fixed for individual beetles. Therefore, hornless males may be committed to particular alternate strategies.

INTRA- AND INTERSEXUAL INTERACTIONS AT BREEDING BURROWS IN THE HORNED BEETLE, *COPROPHANAEUS ENSIFER* (COLEOPTERA: SCARABAEIDAE). M. Otronen, Department of Zoology, A.B.R.G., University of Oxford, South Parks Road, Oxford OX1 3PS.

Coprophanæus ensifer is a large horned beetle, in which, in contrast to many other horned beetle, both males and females possess a long head horn. The species is a carrion feeder and makes nest burrows under carcasses. Interactions between individuals at the burrows were observed and both intra- and intersexual fights were common. In these fights, horn size was the most important predictor of fighting time. Although size differences between individuals are large there was no clear evidence of a dimorphism in behaviour. Large males were more successful in attaining copulations whereas large females were more successful in refusing them. The individuals who started nest building were usually the largest ones in each experiment. The significance of body and horn size and the exceptional existence of the female horn is discussed.

MALE DIMORPHISM AND ALTERNATIVE REPRODUCTIVE BEHAVIORS IN *DENDROBIAS MANDIBULARIS* AUDINET-SERVILLE (COLEOPTERA: CERAMBYCIDAE). S. K. Goldsmith, Faculty of Biological Science, University of Tulsa, Tulsa, Oklahoma, 74104 USA.

Males of *Dendrobias mandibularis* were separated into two morphs, majors and minors, on the basis of relative mandible length. Minor males were the smaller males of the population, and had mandibles that were similar in size and morphology to the mandibles of females. Major males were the larger males of the population, and had mandibles that were disproportionately enlarged. The mandibles were used in intrasexual aggression over feeding sites that were attractive to females. Both size and morph were important in determining the outcome of combat. Major males occupied feeding sites more frequently than expected on the basis of their abundance, and mated at the feeding sites much more frequently than minor males. Minor males occurred in the foliage of the host plant, and tended to mate in the foliage rather than at the feeding sites. Major males mated much more frequently than minor males. Intrasexual selection appears to have played a role in the evolution of both the morphology and the behavior of this species.

ELABORATE SPERMATOPHORES IN KATYDIDS: NUPTIAL GIFTS THAT FUNCTION AS PARENTAL INVESTMENT RATHER THAN IN MATE ACQUISITION (ORTHOPTERA: TETTIGONIIDAE). D. T. Gwynne, Erindale Campus, University of Toronto. Sexual dimorphisms in morphology and anatomy are commonly thought to have evolved in the context of sexual competition but alternative contexts for their evolution are possible. Cook (this symposium) presents evidence that the horns of male dung beetles may have evolved to assist in rearing offspring rather than as weaponry used against rival males. Similarly, theoretical and empirical study of courtship feeding by male insects have indicated that feeding by males has evolved to acquire fertilizations. I present the results of studies of courtship feeding by female katydids on the elaborate spermatophore produced by males. These studies strongly suggest that this investment by males is maintained by natural selection for male parental investment rather than as effort to acquire fertilizations: male donations increase the fitness of offspring and these offspring are fathered by the investing male.

ADAPTATION, COMPROMISE, AND CONSTRAINT: THE DEVELOPMENT, MORPHOMETRICS, AND BEHAVIORAL BASIS OF A FIGHTER-FLIER POLYMORPHISM IN MALES OF *HOPLOTHRIPS KARNYI* (THYSANOPTERA: PHLAEOTHRIPIDAE). B.J. Crespi, Museum of Zoology, University of Michigan, Ann Arbor, MI. 48109-1079, USA.

Males of *Hoplothrips karnyi* (Hood), a haplodiploid, mycophagous, wing-polymorphic thrip in which males fight each other with their forelegs in defense of communal female oviposition sites, were reared individually under varying conditions of food deprivation to investigate the developmental basis of wing polymorphism and the relationships between wing morph, propupal weight, developmental time, and five adult morphological characters associated with fighting and dispersal. Males deprived of food for five days during the second (final) larval instar had smaller propupal weights and were more likely to develop wings than were males deprived of food during the first instar or control males. However, the mean propupal weight of winged males was not significantly less than that of wingless males. Wing morph of female parents was independent of offspring wing morph. Morphometric, experimental, and behavioral data suggest that a trade-off exists between characters associated with male fighting ability and dispersal ability. Wingless males possess relatively larger fore-femora and prothoraces than do winged males, winged males possess relatively larger pterothoraces, and wingless males won fights against each of ten winged males of similar weight as propupae. Wingless males that developed in the experimental treatment that produced winged males were intermediate in size-free shape with respect to winged males and other wingless males. This intermediacy indicates that there may be developmental or selective constraints on the alternative tactics of resource allocation.

FIGHTING, FLYING AND COPULATION: MULTIPLE REPRODUCTIVE STRATEGIES BY DIMORPHIC MALES OF THE ANT, *CARDIOCONDYLA WROUGHTONII*. R.J. Stuart*, A. Francoeur and R. Loiselle, *Department of Zoology, University of Vermont, Burlington, Vermont, U.S.A. 05405 and Université du Québec à Chicoutimi, Chicoutimi, Québec, Canada G7H 2B1.

The genus *Cardiocondyla* is unusual among ants in that males are often wingless and worker-like (ergatoid), and some species have both winged and ergatoid males. In *C. wroughtonii*, ergatoid males have long, sickle-shaped, toothless mandibles which differ markedly from the multitoothed mandibles of the females and most congeneric males. Nests often have numerous queens (polygyny) but typically only one ergatoid male; and this male mates with the young queens produced within the nest. When multiple ergatoid males eclose, they routinely fight until only one remains. Numerous winged males with short toothless mandibles often eclose and coexist with the ergatoid male. These males do not fight and are rarely attacked but will mate within laboratory nests. Winged males and females also appear to conduct mating flights, and this may be the primary mating option of winged males in nature.

Morphology Of Male Competition In Insects: Intrasexual Selection And Secondary Sexual Characteristics

LETHAL FIGHTING AND REPRODUCTIVE STRATEGIES OF DIMORPHIC MALES IN THE ANT GENUS *CARDIOCONDYLA*. K. Yamauchi* and K. Kinomura, Department of Biology, Faculty of Education, Gifu University, Gifu, 501-11 Japan.

Colonies of the ant genus *Cardiocondyla* frequently contain multiple queens and produce both winged and wingless ergatoid males. We studied on their social behavior in 4 *Cardiocondyla* species inhabiting Japan. In *C. wroughtoni* and *C. sp.* A which have both types of males, ergatoid males regularly engage in killing other males at the eclosing pupal stage and in lethal fight with each other, leading to only one ergatoid male per nest. Ergatoid males are morphologically and behaviorally highly specialized for fighting. They are also characterized by their early emergence associated with shortened immature stages and undersized bodies. In contrast, winged males never or scarcely fight with other males. They often emerge synchronously in large numbers and coexist with a resident ergatoid male. Both winged and ergatoid males repeatedly mate within their nests with the winged females produced there, though winged males also conduct nuptial flight. In *C. sp. c* permanently lacking winged males, ergatoid males attack other males at the eclosing pupal stage, but never appear to fight with adult rivals, so that multiple ergatoid males often coexist in single nests for a long period.

HORNS AND SPINES: MALE DIMORPHISM IN *SYNAGRIS* LATREILLE SOLITARY WASPS (HYMENOPTERA: VESPIDAE: EUMENINAE). Robert W. Longair, Department of Zoology, Erindale College, University of Toronto, Mississauga, Ontario, Canada L5L 1C6.

Among the aculeate Hymenoptera, there are relatively few examples of male structural dimorphism and even fewer examples of exaggerated secondary sexual characteristics. The African genus *Synagris*, comprised of 23 or 24 described species and several undescribed species, is remarkable in that males of almost half the species show exaggerated mandibular or clypeal horns, or abdominal spines. Patterns of horn and spine development within species will be examined, and implications to sexual selection and speciation discussed.

The role of such structures in male/male competition and mating behaviour is poorly understood, but suggests that in at least one species, *S. cornuta*, direct competition occurs between males for access to females at nests. Such fighting between males in a highly mobile species may differ from that for beetles. The significance of the potential for female manipulation of offspring size and sex to horn development and the structure of the mating system will be discussed.

FUNCTIONAL MORPHOLOGY OF CERCI IN MALE EARWIGS. R.D. Briçeno and W.G. Eberhard†, Universidad de Costa Rica and Smithsonian Tropical Research Institute, San José, Costa Rica.

The cerci of mature male earwigs differ from those of females and immatures in many species. We attempted to determine the functional significance of male-specific characters by observing courtship, copulation, and male-male aggressive behavior in 12 species in captivity. In some species some male characters appear to function during courtship but not in male-male fights; in others they apparently function in fights but not in courtship; in two cases they permit the male to seize the female just prior to and during copulation. Many male cercal characters may be involved in both courtship and male-male aggression. Thus in contrast with the horns of beetles, which seem to generally function in male-male battles, the cerci of male earwigs appear to have a variety of function.

THE EVOLVED FUNCTION OF THE ABDOMINAL CLAMP OF MALE *PANORPA* (MECOPTERA). Randy Thornhill, Department of Biology, University of New Mexico, Albuquerque, 87131 USA.

There is debate about how the evolved function (selective history) of adaptations should be studied. For example, it has been argued by M.J. Wade that the function of the abdominal clamp of male *Panorpa* is best understood by study of the current selection on the organ, strong selection implying function. However, on the basis of results from a behavioral experiment I argued that the clamp functions in the context of forced copulation, allowing males without resources to circumvent female choice. Wade calculated small intensities of sexual selection in the context of forced copulation in *Panorpa*, and suggested that the clamp may serve some other function. The most appropriate way to study adaptations is by examining their functional design or goal or purpose. Behavioral and morphological analyses of the abdominal clamp reveal that it is designed to accomplish forced copulation. When the clamp is nonfunctional, manipulated males cannot force copulation, but they can successfully mate without force. Among males of single populations, there is a positive correlation between the size of the clamp and the extent to which males use force copulation as a mating tactic.

REPRODUCTIVE COMPETITION AND THE MALE DIMORPHISM IN THE DAMSELFLY *MNAIS COSTALIS* SELYS (ODONATA: CALOPTERYGIDAE). H. Ubukata, Department of Science Education, Kushiro College, Hokkaido University of Education, Kushiro, 085, Japan.

The Japanese *Mnais* is composed of three, closely related species (*M. costalis* Selys, *M. pruinosa* Selys s. str. and *M. nawai* Yamamoto). Males of *Mnais costalis* show an apparent dimorphism, viz. 'orange-winged form' (OW) and 'hyaline-winged form' (HW), as in the rest species. All the females are hyaline winged. OW males have stouter and much more pruinose body and higher ratio of the wing length to the abdominal length than HW males.

Mature OW males occupy territories on a stream and guard their mate ovipositing after copulation. On the other hand, HW males are far less aggressive than OW males and show no tendency to occupy territories unless OW males have been removed. HW males obtain mates by sneaking into the territories of OW males, by intercepting the females visiting territories, or by searching along a stream.

The mating system of *M. costalis* can be regarded as an coexistence of two different mating strategies tightly connected to the male dimorphism. The morphology of OW males must have been favoured by natural/sexual selection to maintain territories and to attract females, while that of HW males is favourable for sneaking. The ratio of two forms are affected by the degree of visibility on a stream.

FACTORS AFFECTING THE COEXISTENCE OF TWO MALE FORMS IN A POPULATION OF DAMSELFLY *MNAIS PRUINOSA* SELYS (ZYGOPTERA: CALOPTERYGIDAE). S. Nomakuchi, Department of Biology, Kyushu University, Hakozaki, Higashi-ku, Fukuoka 812 Japan.

Two male forms of damselfly *Mnais pruinosa* Selys occurred in a stream in Kyushu, Japan; viz. f. *esakii* and f. *strigata*. Territorial behaviour was initiated only by the male of *esakii*, and usually the male led to displacement of *strigata* male. *Esakii* male copulated with female which appeared in the territory, and guarded ovipositing female after copulation. *Strigata* male also copulated with female perched on the branch of tree, but did not guard the female. Copulation frequency of *strigata* male was not different with that of *esakii* male. But the evidence by the field observation is that ovipositing female guarded by *esakii* male was observed two times more than that by herself because of female's recopulation with *esakii* male after mating with *strigata* male. It seems that reproductive success of *strigata* male are decreased by sperm competition. The density of *esakii* male was about two times as that of *strigata* male in the study area.

However, in another study area of Muromi river where two forms of male also coexisted, number of female ovipositing single was more than that guarded by *esakii* male because of many oviposition sites and environmental hazard for establishment of *esakii* male territory. In this area, superiority in male forms' density was the reverse against the Ino river.

The factors influenced on reproductive success in the two forms of male are discussed.

Morphology Of Male Competition In Insects: Intrasexual Selection And Secondary Sexual Characteristics

SEXUAL SELECTION AND PARASITE LOAD IN FIELD CRICKETS.
Marlene Zuk, Department of Biology, University of New Mexico, Albuquerque, New Mexico 87131 USA.

Recent theoretical work suggests that parasites play an important role in sexual selection. According to these ideas, healthy males should have higher mating success than parasitized males, and parasites should influence the evolution of secondary sex characters. I studied the effects of gregarine gut parasites, adult age, and other male traits on male mating success in the field crickets *Gryllus veletis* and *G. pennsylvanicus* (Orthoptera: Gryllidae) to test this and other hypotheses about sexual selection. In field experiments, the number of females a male attracted was correlated with his age, whereas parasite load and body size were unrelated to attractiveness. However, laboratory experiments showed that males infected with parasites produced fewer spermatophores per unit time than did healthier males; because females mate several times before ovipositing, a male's mating success is expected to suffer if he cannot supply multiple spermatophores to a female. Developmental time is also longer for infected nymphs. These results are used to propose a new interpretation of post-copulatory guarding in crickets.

INVESTIGATIONS INTO THE FUNCTION OF 'ANTLERS' IN *PHYTALMIA MOULDSI* McALPINE AND SCHNEIDER (DIPTERA: TEPHRITIDAE).
G. N. Dodson, Department of Entomology, University of Queensland, St. Lucia, Queensland, Australia 4067.

P. mouldsi is known only from a restricted area of rainforest in far North Queensland, Australia. The species displays a striking sexual dimorphism with males possessing lateral cheek projections resembling the antlers of cervids. They exhibit a resource defense mating system in which successful males maintain territories around oviposition sites from which they exclude conspecific males and court females. Interactions between males involved pushing against each other with their heads. Larger males win interactions and mate more often. Interactions between equally sized males are won by the male with larger antlers. Manipulations of antler size influenced the types and outcomes of interactions in ways consistent with the hypothesis that antlers function as an indicator (but not sole determinant) of the dominance of one individual over another. Selective pressures for large size among males may account for the apparent protogynous adult emergence pattern.

INTRASEXUAL SELECTION AND SEXUAL DIMORPHISM IN LEKKING AND SWARMING FLIES. T. Burk, Biology Department, Creighton University, Omaha, Nebraska 68178, U.S.A.

Intrasexual selection has led to a variety of sexually-dimorphic characteristics in lekking and swarming flies. Direct combat involves "horns", "antlers", and stalk-eyes. Dimorphic sense organs result from mate location competition, with male antennae and eyes often being larger and more elaborate than female ones. Signalling competition involves male-produced sex pheromones and acoustic calls, produced by special pheromone and salivary glands, stridulatory structures, and wings of modified shape. Sperm competition may be involved in tarsal and genital characteristics. Many dimorphic features used in courtship may also be used in intrasexual encounters; distinctions between natural selection, intrasexual selection, and intersexual selection forces have not often been carefully made. In some interesting cases, intrasexual selection leads to similarities rather than to differences in the behavior and the morphology of the sexes.

VOLATILE SEMIOCHEMICALS IN HOST-COMMUNITY LOCATION BY EGG PARASITOIDS. L.P.J.J. Noldus¹ and W.J. Lewis². ¹Department of Entomology, Agricultural University, Wageningen, The Netherlands; ²Insect Biology & Population Management Research Lab, USDA-ARS, Tifton, GA, U.S.A.

The process of finding of host communities and individual hosts within communities by egg parasitoids is still poorly understood. Several larval parasitoids of Lepidoptera are known to be guided towards their target by odours resulting from the feeding activity of the host, i.e. the eating caterpillar. In the case of egg parasitoids direct cues from the host stage searched for (i.e. the egg) do not seem to be available, at least not for perception a long distances. Therefore it is supposed to be advantageous for an egg parasitoid to react to host-related cues that have the closest temporal correlation with oviposition. The sex pheromone of the host could function as such a cue, as it indicates the presence of hosts (in reproductive state) in a habitat.

Our research on the noctuid moths *Heliothis zea* and *Manestra brassicae* has indeed revealed that *Trichogramma* spp. do react to the odour of calling female moths and (in the case of *H. zea*) to a synthetic sex pheromone blend. Experiments in a low-speed wind tunnel showed that the behavioural response of the parasitoids consists of arrestment in the area where the odour is perceived, rather than attraction by and oriented movement towards the source of the odour. Here we present new evidence on the mechanism of the behavioural response of the parasitoid to host sex pheromone, and on various factors affecting this response.

ADJUSTMENTS TO THE FORAGING EFFORT OF A PARASITOID, *OPIUS DIMIDIATUS*, SEARCHING FOR LEAFMINER (*LIRIOMYZA TRIFOLII*) LARVAE: EFFECTS OF HOST ENCOUNTERS. J.M. Nelson, Department of Biological Sciences, Simon Fraser University, Burnaby, B.C., Canada V5A 1S6.

An *Opius dimidiatus* female, while searching for leafminer larvae to parasitize, may adjust her foraging effort on a host-containing patch as a result of both successful ovipositions and encounters with already-parasitized hosts.

If each such experience with a host contributes information about the potential profitability of a patch, or the lack thereof, the time a female has allocated to that patch may be modified by changing the length of time she will continue searching following an oviposition, until she leaves (GUT). In addition, adjustments may be made in her turning rate after host encounters, and in the size of the area subsequently searched.

AVAILABILITY OF CRYPTIC LARVAE OF THE STALKBORER, *EOREUMA LOFTINI* (DYAR) (LEPIDOPTERA: PYRALIDAE) TO ATTACK BY HYMENOPTEROUS PARASITES. H.W. Browning* and R. S. Pfannenstiel, Texas Agricultural Experiment Station, Weslaco, Texas 78596.

Hymenopterous parasites of stalkboring lepidopterous larvae have a limited number of strategies by which they may access and successfully attack hosts. The effectiveness with which parasites encounter host larvae is a function of larval behavior, and general strategies identified in studies on *E. loftini* differ according to host instar and plant location. Leafsheath probers attack 1st - 3rd instar borers by ovipositor insertion between leaf layers. Tunnel drillers, on the other hand, attack 2nd - 6th instars by penetrating plant tissue and thus accessing borer tunnels. Additional strategies may be defined based on host stage and location in combination with parasite action required to access that specific host.

Laboratory observations, field cage experiments, and field survey results have quantified the occurrence of host niches corresponding to plant location and stage specificity.

NON-UTILIZATION OF APHID ALARM PHEROMONE TO A PREDATORY LADY BEETLE, *COCCINELLA SEPTEMPUNCTATA BRUCKII* WHILE EXECUTING LOCAL SEARCH. Kiyoshi Nakamuta, Lab. of Biol., Tokyo Univ. Agric. & Technol., Fuchu, Tokyo 183, Japan

Local search after having found a food item is known from predatory coccinellids. While executing local search, lady beetles might utilize any chemical produced by their prey for orientation toward an additional prey item. If so, it may be possible for a lady beetle to utilize the alarm pheromone emanating from the aphid it attacked. In the present paper, the affect of aphid alarm pheromone on the local search is delineated using synthesized β -farnesene.

The pathway of lady beetle in an arena was recorded on a video tape after exposure to one of the following stimuli: consumption of an aphid, consumption of a dummy prey or contact with a filter paper permeated with 200 ng β -farnesene. Three search parameters are obtained by the video motion analyzer: locomotory rate (mm/s), turn rate (degrees/s) and meander (degrees/mm; turning per unit distance). Locomotory rate was significantly higher after contacting β -farnesene than consumption of a prey or a dummy prey. Both turn rate and meander were significantly lower after contacting β -farnesene than consumption of an aphid or a dummy prey. These results suggest that β -farnesene is not utilized as an orientational cue to lady beetle for executing local search.

APHID COLONY ASSESSMENT BY THE HOVERFLY *EPI-SYRPHUS BALTEATUS* (DE GEER) (DIPTERA: SYRPHIDAE)

E. Kan*, T. Hidaka and M. Sasakawa, Department of Zoology, Kyoto University and Ent. Lab., Kyoto Pref. University, Kyoto, 606 Japan.

The aphidophagous syrphid fly, *E. balteatus*, actively visits maple trees in early spring and oviposits adjacent to the colonies of two species of maple aphids. Female flies selected, as their oviposition sites, small, young colonies with wingless aphids and neglected large, older colonies including winged ones. It is suggested that the female flies are assessing the value of aphid colonies as the sufficient food resources to support the successful development of their larvae. Females are selecting those colonies which are 'promising'.

PHYSIOLOGICAL CORRELATES OF HOST SEEKING BEHAVIOR IN MOSQUITOES. M. F. Bowen, Department of Biological Sciences, Northern Illinois University, DeKalb, Illinois 60115, USA.

Host seeking behavior in mosquitoes is considered to be essential for successful blood feeding in the field. Its expression is closely correlated with specific peripheral sensory changes associated with antennal receptors that are sensitive to the host attractant, lactic acid (LA). LA receptors of high sensitivity are consistently and exclusively found on the antennae of actively host seeking females; such highly sensitive receptor responses are never observed on non host responsive females. The absence of high LA receptor sensitivity is characteristic of females that are 1) teneral, 2) maturing eggs, or 3) in reproductive diapause. The termination of the diapause state is associated with the resumption of host seeking and the appearance of increased peripheral receptor sensitivity to LA. Possible relationships between these physiological conditions and their effects on receptor sensitivity are discussed.

DUAL OVIPOSITIONAL BEHAVIOR OF APHIDENCYRTUS APHIDIVORUS (MAYR), AN APHID HYPERPARASITOID (HYMENOPTERA: ENCARTIDAE). D.J. Sullivan* and M.J. Kanuck, Department of Biological Sciences, Fordham University, Bronx, New York 10458 - USA

In most genera of aphid hyperparasitoids or secondary parasitoids, the female wasp attacks the primary parasitoid host either while the parasitized aphid is still alive or after the mummy is formed. Aphidencyrtus aphidivorus is unusual, however, in having a "dual" ovipositional behavior. The adult female wasp can oviposit through both a live parasitized aphid and a mummified aphid into the primary host parasitoid. The egg hatches inside the host larva, and then the hyperparasitoid larva feeds endophagously and kills the primary host. In choice experiments, 82% of the female wasp A. aphidivorus preferred to attack the primary parasitoid larva through the mummy, while only 18% chose the live parasitized aphids for oviposition. The sex ratios of progeny resulting from both ovipositional behaviors showed no statistical difference, but 1.25 female:1 male.

LEKING BEHAVIOR IN TWO SYMPATRIC TEPHRITID FRUIT FLIES OF THE GENUS ANASTREPHA. M. Aluja*, J. Hendrichs and M. Cabrera, Department of Entomology, Fernald Hall, University of Massachusetts, Amherst, MA 01003, U.S.A.

The mating behavior of Anastrepha ludens and A. obliqua was studied on a field caged mango tree. Systematic observations included general behavioral patterns, lekking behavior and intra and interspecific interactions. We discovered strong female sexual selection, multiple matings by males but not females (with one exception), and a clear mating advantage of resident males. Even though interspecific leks were formed and some unsuccessful interspecific mating attempts were observed, both species showed a marked temporal separation in mating activity during the day. A. ludens was clearly crepuscular in its matings habits while A. obliqua remained sexually active during most of the day.

ADULT SURVIVAL AND REPRODUCTIVE SUCCESS IN A DAMSELFY: MEASUREMENTS OF SELECTION FOR MALES AND FEMALES. Bradley Anholt, Dept. of Zoology, University of British Columbia, Vancouver, British Columbia, Canada. V6T 2A9

Enallagma boreale (Zygoptera: Coenagrionidae) has a strongly male biased sex ratio at the mating site. Males are not territorial; it is pure scramble competition for mates. By manipulating larval density and food availability, I was able to raise adults of a much wider range of sizes and dates of emergence than are normally present. Newly emerged adults were given a unique mark and released to determine the effect of these manipulated phenotypic characters on adult fitness. Analysis was broken into two episodes of selection. Survival to reproductive maturity and mating success on attainment of reproductive maturity.

Selection estimates showed that large, early emerging males were more likely to survive to sexual maturity. Of males surviving to this stage, small males copulated more often than large males. Female survival and mating success was not correlated with any phenotypic character.

SIGNIFICANCE OF THE LEK MATING SYSTEM IN TEPHRITID FRUIT FLY SPECIES IN HAWAII. K.Y. Kaneshiro*, K. Kanegawa, J. Kurihara, A. Ohta and T. Whittier, Hawaiian Evolutionary Biology Program, University of Hawaii, Honolulu, Hawaii 96822

We have been investigating the mating system of four species of tephritid fruit flies in Hawaii and have discovered that all display some form of lek mating behavior. The Mediterranean fruit fly (medfly), Ceratitis capitata, display classical lek behavior where small groups of males form aggregations to which females are attracted for mating. On the other hand, in the melon fly, Dacus cucurbitae, it appears that females establish "territories" to which males arrive and perform courtship and where mating occurs. We have only preliminary observations about the mating system of the other two species, Dacus dorsalis (oriental fruit fly) and D. latifrons (malaysian fruit fly), but it is apparent that both of these species also exhibit a lek system similar to that of the medfly. We are now incorporating our observations of the mating systems of these species in the natural population in developing selection protocol for producing a laboratory strain with improved behavioral quality. Such strains will be important for increasing the effectiveness of the Sterile Insect Release Method for control of these species.

RELATIONSHIP BETWEEN SPERMATOPHORE MASS AND LIPID COMPOSITION IN PSEUDALETIA UNIPUNCTA (HAW.) (LEPIDOPTERA: NOCTUIDAE).

L.D. Marshall* and J.N. McNeil, Département de biologie, Université Laval, Ste-Foy, Quebec, Canada G1X 3X6.

Most studies of male nutrient investment in insects have assumed that the mass of the spermatophore passed from male to female during copulation is an appropriate estimate of its value to a female. Investigation of this assumption, however, has shown that no relationship exists between either lipid or hydrocarbons contained in a spermatophore and its mass. Since the hydrocarbons found in the spermatophore are similar to those found in eggs, and thus a potential male nutrient investment, we question the use of mass as an estimate of male investment in offspring and suggest that much of the debate concerning the importance of spermatophores to explanations of mating system biology is due to an inappropriate measure of these investments.

GENETICS AND EVOLUTION OF FEMALE CHOICE IN INSECTS P.O'Donald and M.E.N.Majerus, Department of Genetics, University of Cambridge, Downing Street, Cambridge England CB2 3EH.

The theory of sexual selection by female choice rests on the premise that females have genetic preferences to mate with specific male phenotypes. The female preference selects the males and is itself selected because the preferred males carry the genes for the females' preference. This can produce a 'runaway process' in the evolution of the preferred phenotype and preference.

So far, female choice has been shown to be genetic only in the ladybug Adalia bipunctata and Drosophila melanogaster. In some ladybug populations, melanic males (black with red spots) are preferred to non-melanics (red with black spots). Preference for melanics has been raised in selection experiments. Isofemale lines, set up from a high preference line, showed variation in preference that could be explained by a single dominant gene. Further isofemale lines have been set up from a natural population in order to assay the variation in female choice and to test the single gene model.

On the basis of the results of the genetic experiments, a detailed population genetic model is being constructed to describe the process of sexual selection and the evolution of female choice in Adalia bipunctata.

SELECTION FOR "SUPERMALES" IN THE MEDITERRANEAN FRUIT FLY (MEDFLY), CERATITIS CAPITATA. A.T. Ohta* and J.E. Kurihara.

Previous investigations of the mating system of the medfly have shown that strong sexual selection exists in this species. Our present investigations revealed that only 39% of the eclosing adult males will mate (16% of these being single maters and 23% being multiple maters) with multiple mating males accounting for more than half (55%) of all matings. Thus, a selection program was started to attempt to increase the mating ability of the males. After only two generations of selection (with at least one generation of no selection between) for multiple mating males, male and female choice experiments of selected lines versus stock flies showed an apparent increase in the mating ability of the selected line males. In addition, the data suggest that some changes may have also taken place in females of these selected lines. Field tests of these selected line males are planned for the spring when the field populations will be large enough for a more accurate assay of the mating ability of these flies. The establishment of a stock of flies with increasing mating ability can be important in increasing the effectiveness of the Sterile Insect Release Method (SIRM) used in the control of these flies.

COSTS AND BENEFITS OF POLYGAMY IN A TEPHRITID FRUIT FLY, RHAGOLETIS POMONELLA (WALSH) (DIPTERA:TEPHRITIDAE).

S.B. Opp*, and R.J. Prokopy, Department of Entomology, University of Massachusetts, Amherst, Massachusetts, USA 01003

Both male and female apple maggot flies, Rhagoletis pomonella, mate multiply, a mating system referred to as polygamy. With unlimited oviposition sites in the lab, females show maximal oviposition and fertility when multiply mated. When foraging in a field-cage in which males are present and guarding fruit (oviposition sites), multiply mated females suffer from decreasing oviposition rates, presumably because they are avoiding males and losing access to oviposition sites. Males benefit from mating with non-virgin females because a high degree of sperm precedence occurs, as determined by starch gel electrophoresis.

OVIPOSITION BEHAVIOUR AS A DETERMINANT OF HOST PLANT SPECIFICITY IN THE GENUS *EUPTERYX* CURTIS (CICADELLIDAE: HOMOPTERA). L. Hocking, Department of Zoology, University College, Cardiff, Wales, U.K. CF1 1XL.

The distribution of an insect herbivore is determined by a number of factors including feeding and oviposition preferences. Among relatively immobile early stages the choice of host plant by the ovipositing female is particularly important.

Host plant specificity of generalist and specialist species in the genus *Eupteryx* are examined experimentally through nymphal feeding preference and adult oviposition preference assays using host and non-host plant species. Effects of the host plant are also investigated by transferring early stages to different host and non-host plant species.

MODULATION OF FRUIT-FORAGING BEHAVIORS OF FEMALE *CERATITIS CAPITATA* (WIEDEMANN) (DIPTERA: TEPHRITIDAE) THROUGH CHEMORECEPTION OF VOLATILES INDICATIVE OF DIFFERENT MATURATION STATES OF NECTARINES. D. M. Light* and E. B. Jang, WRRRC, USDA-ARS, 800 Buchanan St., Albany, CA 94710 USA and USDA-ARS, P. O. Box 4459, Hilo, Hawaii 96720 USA.

The impact of olfaction on fruit foraging and ovipositional behaviors of *C. capitata* (medfly) has not been reported. Nectarines are a highly preferred host of medflies; with soft, ripening fruits preferred over hard, immature, green fruits. The headspace volatiles emanating from various maturation states of nectarines were identified. Electroantennogram (EAG) responses to these compounds were recorded. Certain esters, indicative of a ripened fruit-state and "green-leaf volatiles" (GLVs), indicative of an immature or green fruit-state, elicited the largest EAG responses. Dual choice bioassays were performed in a flight-tunnel to observe the attraction, arrestment, and ovipositional responses of female medflies to fruit models. Either "ripe" nectarine aroma or the same "ripe" nectarine aroma plus various test volatiles emanated from the models. The behavioral preference for models emanating "ripe" nectarine aroma was enhanced by the addition of these "ripe-state" esters and disrupted by these "unripe-state" GLVs.

FACTORS AFFECTING TREE SELECTION AND ACCEPTANCE OF CERTAIN *EUCALYPTUS* SPP. BY THE DEFOLIATING PAROPSID, *CHRYSOPHTHARTA BIMACULATA* ERICH. (COLEOPTERA: CHRYSOMELIDAE). J.L. Madden*, Haifeng Li and A. Leon, Department of Agricultural Science, University of Tasmania, Box 252C, G.P.O., Hobart, Tasmania, Australia, 7001.

The Tasmanian eucalyptus leaf beetle, *Chrysophtharta bimaculata* is Tasmania's most severe forest insect pest, attacking young to mature stages of commercially valuable *Eucalyptus regnans*, *E. delegatensis* and *E. obliqua* in natural stands and plantations. These tree species, collectively termed "ashes", belong to the subgenus *Monocalyptus* but recently significant defoliation of the introduced mainland pulpwood species, *E. nitens*, by *Ch. bimaculata* has occurred even though it belongs in the subgenus *Symphomyrtus*. The closely related Tasmanian species *E. globulus* is not attacked.

Investigations have shown that initial attraction to trees is influenced by the colour of foliage, whereas specific host recognition only occurs on leaves through the perception of chemosensory cues via the maxillary palps. Phytochemical studies have been made and findings will be discussed in relation to those obtained in bioassay.

THE CHEMICAL BASIS OF HOST-PLANT SELECTION BY THE SWEET POTATO WEEVIL, *CYLAS FORMICARIUS ELEGANTULUS* (SUMMERS) (COL.: CURCULIONIDAE). S.F. Nottingham*, D.D. Wilson, K.-C. Son, R.F. Severson and S.J. Kays, Department of Horticulture, University of Georgia, Athens, GA 30602, USA. Host-plant selection involves a sequence of behaviors; initial host-location, acceptance, feeding, and oviposition by the females. Each selection stage is potentially mediated by host-plant (*Ipomoea batatas* (L.) Lam.) chemistry. Both sexes responded to host-plant volatiles, while levels of feeding by females on leaves and storage roots, and oviposition on roots, were all found to vary between cultivars. Analysis of the volatiles and leaf and root surface chemicals was done for four cultivars having different levels of resistance to the weevil. Chemical differences between susceptible and resistant cultivars suggested a regulatory role for certain host-plant chemicals which are being bioassayed for their behavior-modifying effects on the weevil. Cultivars may have enhanced resistance to the weevil by being chemically unfavourable at more than one host-selection stage.

BEHAVIOURAL ADAPTATIONS OF INSECTS THAT FEED ON THE PHOTOTOXIC PLANT *HYPERICUM PERFORATUM*. Paul Fields, Thor Arnason* and Benard Philogène, Dept. of Biology, University of Ottawa, Ottawa Ont., Canada, K1N 6N5.

Hypericum perforatum contains hypericin, an extended quinone that has greatly increased toxicity to insects in light. We have studied three insects that are able to feed on *H. perforatum* despite the presence of the phototoxin. Early instars of *Chrysolina quadrigemina* and *C. hyperici* (Coleoptera: Chrysomelidae) are hidden from direct sunlight by the leaf buds they feed on. Late instar larvae, too large to be hidden by the leaf buds, spend most of their time concealed in the soil, only feeding for a brief period at dawn. Larvae die if forced to remain in the light, suggesting that cryptic behaviour is necessary to avoid phototoxicity. Adult *Chrysolina* spp. also feed on *H. perforatum*, but unlike the larvae, they are found in full sunlight. These differences in behaviour may be related to the ability of the adult cuticle to block out most visible light, whereas the larval cuticle is transparent. Unlike the *Chrysolina*, *Anaitis plagiata* (Lepidoptera: Geometridae) larvae do not avoid the light until the last instar, and do not die when exposed to light. Also, *A. plagiata* larvae are much more tolerant to the phototoxin alpha-terthienyl than are *Chrysolina* larvae, suggesting that *A. plagiata* have better quenching systems.

NEURAL DETECTION AND BEHAVIORAL ROLE OF GREEN LEAF VOLATILES IN THE BOLL WEEVIL, *ANTHONOMUS GRANDIS* BOH. (COLEOPTERA: CURCULIONIDAE). Joseph C. Dickens, USDA-ARS, Boll Weevil Research Unit, Mississippi State, Mississippi, USA, 39762.

The importance of olfaction in the behavior of insects is well-known. Insect-produced volatiles (e. g. pheromones) and host plant odors may facilitate location of conspecifics for mating, and orientation to acceptable host plants. In several insect species, pheromones and plant odors may act in synergy, each enhancing the others attraction. It seems likely that chemical messengers would be especially important to monophagous or oligophagous plant feeders. The boll weevil is narrowly oligophagous feeding primarily on cotton, *Gossypium hirsutum* L., and closely related Malvaceae. Once male boll weevils locate their host plant feeding ensues, and they release in their frass an aggregation pheromone. Recent single cell recordings from antennal olfactory receptors revealed not only cells sensitive to individual pheromone components, but also cells which were activated by particular host plant odors, e. g. specific green leaf volatiles, six-carbon primary alcohols and aldehydes formed by oxidative degradation of plant lipids. Subsequent field tests demonstrated these odors to be relatively unattractive when presented alone, but when presented in combination with the pheromone enhanced its attractiveness. The results are discussed with regard to the ecology of the boll weevil and host plant selection strategies by insects.

HOST PLANT SELECTION BY *SPODOPTERA LITTORALIS*: DO ADULTS AND LARVAE USE THE SAME CRITERIA? M.S.J. Simmonds,¹ and W.M. Blaney,² Behavioural Entomology Group at 1. Jodrell Laboratory, Royal Botanic Gardens, Kew, England, TW9 3DS and 2. Department of Biology, Birkbeck College, Malet Street, London, WC1E 7HX, England.

The feeding behaviour of both adult and larval stages of *Spodoptera littoralis* is influenced by a similar range of plant compounds. In the larvae electrophysiological responses to these compounds were obtained from the maxillary styloconic sensilla and in the adult from the styloconic sensilla of the proboscis. The sensory responses to specific compounds were correlated with the effects they had on the insect's feeding behaviour. Both developmental stages were stimulated to feed by sugars (e.g. fructose and glucose) and amino acids (e.g. leucine, alanine, GABA and valine), whereas some flavonoids, terpenoids and amines deterred feeding. The concentrations of the compounds that either stimulated or deterred feeding differed between the developmental stages. Adults were more sensitive than larvae to sugars and amino acids; larvae were more affected by plant allelochemicals than the adults.

The ecological significance of these results is discussed with reference to the chemicals found in the insect's host plants.

HOST-FINDING BEHAVIOUR OF THE ADULT ONION MAGGOT, *DELIA ANTIQUA* (MEIGEN) IN RELATION TO RESOURCE LEVEL. G.J.R. Judd, AGRICULTURE CANADA, RESEARCH STATION, HARROW, ONTARIO, CANADA NOR 1G0.

Phytophagous insects foraging for an oviposition site may perceive the environment at several hierarchical levels: the habitat, the patch and the resource item itself. The behaviour of adult onion maggots, *Delia antiqua* (Diptera: Anthomyiidae) foraging for *Allium* spp. (onion) host plants, varies with each resource level. Gravid females move randomly with respect to mean wind direction in vegetated and nonvegetated habitats lacking host plant odour. Patch-finding behaviour is initiated at least 100 m downwind when females encounter host plant, *Allium*-produced alkyl sulfides like dipropyl disulfide. Patch-finding search is characterized by directional flight and positive anemotaxis. Following host-plant patch discovery, mated, gravid females forage for lower level visual and olfactory cues. Searching within the host plant patch is nondirectional with respect to mean wind direction. Ovipositing females foraging among host plants respond to a complex bouquet volatiles emitted by damaged host plants. Acceptance of the oviposition resource after host finding, is increased by the release of ethyl acetate from the damaged hosts.

A FEEDING DETERRENT EFFECT OF VARIOUS EXTRACTS OF *ABRUS PRECATORIUS* SEEDS TOWARDS THE COTTON LEAFWORM *SPODOPTERA LITTORALIS* (BOISD.). N.Z. Dimetry* and E.P. Abdallah, Laboratory of Plant Protection, National Research Centre, Dokki, Cairo, Egypt.

In feeding bioassays, the application of some extracts of *Abrus precatorius* seeds on castor oil leaf discs demonstrated a significant reduction in the leaf area consumed and a considerable decrease in the body weight gain by the sixth instar larvae of *S. littoralis*. The other extracts of *A. precatorius* seeds tested gave insignificant decrease either in the food consumed or the average body weight of the larvae. The percent pupation and the weight of pupae obtained are significantly reduced; the fecundity of the resulting female moths is significantly decreased in case of larvae offered leaf discs treated with petroleum ether or water extracts.

FACULTATIVE DEPOSITION OF AN OVIPOSITION DETERRENT PHEROMONE BY *ATHERIGONA* (DIPTERA: ANTHOMYIIDAE). K.P. Salin, K.R. Kanaujia*, Department of Entomology, G.B. Pant University of Agriculture & Technology, Pantnagar, 263 145, India.

Ovipositional behaviour of *Atherigona soccata* Rondani in maize ecosystem is shown to be controlled by the realization of impending larval competition. Non-tillering characteristic of maize seedlings induced female flies to lay single egg per plant coated with deterring pheromone to avoid inevitable larval competition. On the other hand, flies resorted to multiple egg laying on wild sorghum plants, an alternate host showing profuse tillering that helped the flies to avoid larval competition. Presence of a "wild sorghum factor" was established through which flies discriminated between these two host plants and conserved energy required for the production of pheromone to occasions when it lays eggs on maize plants. This is an example of rarest phenomenon of facultative deposition of pheromone.

PHYTOCHEMICAL TOXINS CAUSE CHANGES IN ACCEPTABILITY OF PLANT FOODS: FOOD AVERSION LEARNING AND FOOD SELECTION IN THE POLYPHAGOUS ACRIDID *SCHISTOCERCA AMERICANA*. J. C. Lee*, and E. A. Bernays, Department of Entomological Sciences, University of California, Berkeley, California, 94720 USA.

Individuals of the polyphagous acridid *Schistocerca americana* are capable of associating the gustatory cues of a plant food with the deleterious effects of a plant toxin which is injected just after ingestion of the food. This associative process is manifested in a reduction in acceptability of the food plant. Food aversion learning has been observed after injections of a number of chemically diverse plant compounds; the behavior has also been tested with a number of plant foods. Observations of individual feeding behavior with foods of varying quality suggest an important role for such a learning capability in food selection.

THE IMPORTANCE OF POLLEN ON THE REPRODUCTIVE BIOLOGY OF THE SUNFLOWER MOTH, *HOMOEOSOMA ELECTELLUM*. J. Delisle*, C.R.L., 1055 rue du PEPS, C.P. 3800, Ste. Foy, P.Q., Canada, and J.N. McNeil, Département de biologie, Université Laval, Ste. Foy, P.Q. Canada, G1K 7P4.

In field studies it has been shown that the phenological stage of the sunflower influenced the oviposition behaviour of *H. electellum*, with females preferring to oviposit in sunflower heads that have recently opened. This suggests that an oviposition stimulus may be associated with the sunflower pollen. The data presented in this study clearly showed a positive relationship between the oviposition of *H. electellum* females and pollen or pollen extract concentrations. Pollen also stimulated the pre-copulatory behaviour of *H. electellum*. In the presence of pollen females starting calling at a significantly younger age than those in the presence of sucrose or pollen residue. Furthermore, once calling had been initiated pollen increased the duration, as well as the number of calling bouts, and accelerated the maturation of eggs. While the influence of pollen on the timing of the reproductive biology of *H. electellum* is crucial for the survival of young larvae, that feed exclusively on loose pollen, it is suggested that the availability of this resource may also regulated other activities, such as adult dispersal.

ELECTRONIC RECORDING OF FEEDING BEHAVIOR OF GREEN HAIRY CATERPILLAR, *RIVULA ATIMETA* (SWINHOE) LEPIDOPTERA: NOCTUIDAE ON RICE PLANTS, WILD RICES, AND GRASSY WEEDS. R. C. Saxena* and E. B. Medina, Department of Entomology, International Rice Research Institute, P. O. Box 933, Manila, Philippines.

The feeding activity of 4th instar *R. atimeta* larvae was monitored on 30-d-old potted plants of susceptible 'IR36' and moderately resistant 'Nagadhan' rice varieties (*Oryza sativa*), wild rice (*Oryza brachyantha*), and two grassy weeds (*Echinochloa colona* and *Leersia hexandra*). Insect feeding rate was significantly higher on 'IR36' plants (0.25 mm²/min) than on *E. colona* (0.11 mm²/min) or on *L. hexandra* (0.15 mm²/min). Feeding rate was also significantly less on a hybrid between *O. sativa* and *Oryza rufipogon* (0.14 mm²/min), but not on moderately resistant 'Nagadhan' rice (0.19 mm²/min) or on *O. brachyantha* (0.17 mm²/min). The insect spent 82% of its time feeding on leaf blades of susceptible 'IR36' plants, in contrast to 54% on 'Nagadhan' or on wild rice *O. brachyantha*, 59% on *E. colona*, 65% on the *O. sativa* x *O. rufipogon* hybrid, or 76% on *L. hexandra*.

STRATEGIES DE PONTE CHEZ *FORFICULA AURICULARIA* (DERMAPTERA: FORFICULIDAE). J.C. Tourneur*, J. Gingras, Département des Sciences biologiques, Université du Québec à Montréal, C.P. 8888, Succ. A, Montréal, Canada H3C 3P8 et M. Vancassel, Laboratoire d'Ethologie, Université de Rennes I, Avenue du Général Leclerc, 35042 Rennes Cédex, France.

Il a déjà été démontré par Vancassel que des populations de climat tempéré doux (Pacé, France) et de climat tempéré froid (Font-Romeu, France) présentent des différences quant au nombre de pontes annuelles et au nombre d'oeufs pondus par ponte. La présente étude vise à comparer des populations de Deux-Montagnes (Québec, Canada) et Truro (Nouvelle-Ecosse, Canada) à cet égard. Il semble aussi que le délai écoulé entre la mue imaginale et la ponte varie entre populations. Les résultats sont analysés en regard de ce qui est déjà connu à ce sujet dans la littérature nord-américaine. L'hypothèse d'une introduction multiple de l'espèce en Amérique du Nord est envisagée.

MIGRATION OF THE HIMALAYAN WINGLESS GLACIER MIDGE (DIAMESA SP.) : SLOPE DIRECTION ASSESSMENT BY SUN-COMPASSED STRAIGHT WALK. Shiro Kohshima, Department of Zoology, Faculty of Science, Kyoto University, Kyoto 606, Japan.

Orientation mechanism of the glacier midge (Chironomidae; Diamesa sp.) was studied in a Himalayan glacier (Yala glacier) in Nepal. This insect, a newly found cold tolerant chironomid characterized by reduced wings and antennae, is unable to fly, and is found on the surface of the glacier and in small cavities beneath it. The larvae grow in the melt-water drainage channels under the ice and feed on blue-green algae and bacteria growing there. The insect is the first to be found which spends its entire life cycle in the snow and ice of a glacier : the coldest insect habitat ever recorded. Female adults have a very long life span and migrate toward the upper part of the glacier by walking. They walk straight by means of a sun-compass ; the direction of which could be altered by changing the apparent position of the sun with a hand mirror. Field data suggested that the direction of their walk was corrected by some information on the slope direction . They seemed to assess the slope direction during walking straight by means of sun-compass. The migration is thought to be a kind of upstream migration well known in stream insect or that for overwintering.

ORIENTATION FLIGHT OF ACANTHOPLUSIA AGNATA (LEPIDOPTERA: NOCTUIDAE) TO ITS SEX PHEROMONE SOURCE. Kenjiro Kawasaki Division of Entomology, National Institute of Agro-Environmental Sciences, Tsukuba, Ibaraki 305, Japan

Orientation flight of male Acanthopplusia agnata to its sex pheromone source and trap capture were observed in a wind tunnel. A water pan trap (12cm petri dish), with 0.1 FE virgin female extract on a small piece of filter paper, captured 10% of male released, whereas a cone type trap (15cm diameter and 30cm length cylinder with mesh cone in it) captured 38.7% of male. The result was caused by male behavior: male landed on the surface of the cylinder and walked up into the trap. On the other hand, male did not drop into water pan so frequently. The effect of sex pheromone plume shape on the male orientation flight will be discussed with Spodoptera litura.

THE ROLE OF THE MINOR COMPONENTS OF THE FEMALE SEX PHEROMONE OF THE SMALLER TEA TORTRIX MOTH, ADOXOPHYES SP. (LEPIDOPTERA: TORTRICIDAE). Kokubun, T. (Institute of Agriculture and Forestry, University of Tsukuba, Tsukuba, Ibaraki 305, Japan)

The sex pheromone of the smaller tea tortrix moth, Adoxophyes sp., consists of two major components (Z9-14:Ac, Z11-14:Ac) and two minor components (E11-14:Ac, 10Me-12:Ac). The behavioural role of the minor components was studied by the wind tunnel and in-flask observations. Addition of minor components in a natural ratio to sub-effective dose of major components at which no biological response was observed, significantly enhanced the responsiveness of males' upwind flight in the wind tunnel and of mating dance in flask assay. Therefore, the addition of the minor components lowered the threshold of the male sensitivity to the major components and suggested that they extend an active space of major components. Field experiments supported this suggestion. Another wind tunnel experiments showed that E11-14:Ac reinforced the landing behaviour. On the other hand, the duration of mating dance was extended by addition of 10Me-12:Ac to two major components at two stimulatory conditions (continuous and single pulse). The approaching behaviour to the pheromone source of four component-mixture differed from that to major components. Therefore, the function of the minor components was also demonstrated to activate the male searching behaviour for the females. Moreover, the other experiments showed that the minor components inhibited the development of sensory adaptation or habituation.

ATTRACTION OF FEMALE TRICHOPLUSIA NI (HUBNER) (LEPIDOPTERA: NOCTUIDAE) TO MALE-PRODUCED PHEROMONE. P.J. Landolt* and R.R. Heath, USDA, ARS, Insect Attractants, Behavior and Basic Biology Research Laboratory, Gainesville, Florida 32604.

Female cabbage looper moths have been shown to be attracted to live males in cages and to hexane extracts of males. In a flight tunnel, females exhibited upwind anemotaxis and plume tracking behavior to the odor source. The attractant was found to originate in the terminal genital hairpencils of males.

VISUAL FLIGHT CONTROL IN WASPS: THE OCELLI CONTROL SHADING AND ANTISHADING YAW RESPONSES IN TETHERED FLIGHT. G.Kastberger, Institute of Zoology, Department of Neuroethology, University of Graz, Austria, Europe.

The light-induced turning responses of flying wasps (tethered to a torque transducer in the wind tunnel) around the yaw axis were investigated under open loop and a 3-light regime: Two side lights for weak stimulation of compound eyes and ocelli (1200 Lux), and one light from dorsal to strongly illuminate the ocelli (200 000 Lux). Six kinds of ocellar occlusion were used, either with or without blinding the dorsal regions of compound eyes. The side lights were switched on or off every 20s and the ocellar light was switched on (Antishading pulse) or off (Shading pulse) for 3s with a variable, randomly chosen delay (2-12s) after every side light switch. A complex strategy (a concept of primary turn and a hierarchical net of plausibility checks) confirms the evaluation of the small light-induced turns in strong noise (which is probably elicited by anemotaxis).

The results lead to some functional rules for median and lateral ocelli and generally agree with the simple models proposed by Jander and Barry (1968) for the walking cricket and locust in phototactic responses: phototactic orientation is controlled by the ocelli; the mode of ocellar control is determined by ocellar illumination; the lateral ocelli command the direction of phototactic movements; the median ocellus controls the commands of the lateral ocelli. Furthermore, shading / antishading-reflexes are also controlled by the ocelli and they probably trigger some orienting subsystems which drive phototactic responses. In particular, the ocelli play an important part in triggering (anti-) shading reflexes, determining direction and strength of yaw-responses in an complex and hierarchical order in community with the dorsal parts of compound eyes.

VISUAL AND ACOUSTICAL ORIENTATION IN PERIODICAL CICADA FLIGHT [MAGICICADA CASSINI (FISHER): HOMOPTERA: CICADIDAE: TIBICININAE]. T.E. Moore*, Museum of Zoology, University of Michigan, Ann Arbor, MI. 48109-1079, U.S.A., F. Huber, T. Weber, U. Klein, and C. Bock, Max-Planck-Institut für Verhaltensphysiologie, D-8131 Seewiesen, F.R.G.

Males and females perform low-altitude (under 5 m), short-distance (under 15 m) flights in their natural habitat at flight speeds of 3-6 m/s. Wing beat frequencies of tethered animals at 24°-26°C average 28.8/s. Mean body temperature in the field for flying individuals was 29.5°C, averaging 4.6° above ambient. Heads of males are significantly smaller than those of females; but compound eyes are about the same size, containing 13,000 facets in males and 14,000 facets in females. Females respond to playbacks of just the frequency/intensity sweep at the end of a buzz of a male's calling songs by flying within 1.2 m above the ground from distances of 2-8 m, mostly from lower vegetation. Cicadas flew normally after covering all ocelli, both caudal halves, or both dorsal halves of compound eyes. Cicadas with a) one or both compound eyes completely covered, or b) with frontal halves, ventral halves, monocular fields, or binocular fields of both eyes covered flew to higher altitudes (beyond 50 m) and for longer distances (beyond several hundred m).

FLIGHT BEHAVIOR OF *CARPOPHILUS HEMIPTERUS* (L.) (COLEOPTERA: NITIDULIDAE): TRANSITION FROM DISPERSIVE TO VEGETATIVE FLIGHT. J.L. Blackmer* and P.L. Phelan, Department of Entomology, Ohio State University, O.A.R.D.C., Wooster, Ohio 44691, USA.

The free-flight behavior of *Carpophilus hemipterus* was investigated using a vertical wind tunnel. Light presented from above induced a phototactic flight response, especially in beetles 72-144 h old. After a period of vertical flight (ranging from 1-100 min), phototactic response declined and flight characterized by reduced vertical, but greater horizontal displacement occurred. We suggest that the initial flight type represents a dispersive flight, while the latter is a vegetative or host-finding flight. These two were further distinguished by the absence of optomotor and chemo-orientated responses during phototactic flight. The majority of flights of both males and females lasted less than 15 min; however, the range of flight durations for females was much greater with about 10% flying longer than 45 min and some as long as 100 min. A bimodal flight periodicity was recorded for both sexes with a small peak of activity occurring shortly after the beginning of photophase and a much larger flight peak occurring three to zero h prior to scotophase. Interaction of other stimuli, such as color and chemical cues on in-flight phototactic response will be discussed.

EVOLUTIONARY ORIGINS OF MIMETISM IN INSECTS. S.Ž. Glumac, Institute of Biology, I.Djuricica str. 6, 21000 Novi Sad, Yugoslavia

It is considered that mimetic colouring, composition and behaviour appear in different species of insects often independently on their systematic place and similarity, influence of the conditions which have caused the phenomenon of these adaptations. Then, through the selection, these adaptations can take on certain new, protective functions both in the species that have been imitated and those that imitate. This process is intensified in the species having a lower degree of survival under the conditions of greater resistance of the environment. The example of the genera *Bombus* (Hymenoptera) and *Volucella*, *Arctophila* and *Pocota* (Diptera) illustrates this phenomenon. The body overgrown with hairs, appeared as a structure providing thermoregulation and preventing sudden changes of the body temperature through the selection of colouring, can take on the protective function against unspecific predators.

SIGNIFICANCE OF ONTOGENETIC COLOR CHANGE IN *LARGUS CALIFORNICUS* (VAN DUZEE) (HEMIPTERA: LARGIDAE). C. L. Booth, Department of Biology, University of California, San Diego, La Jolla, California, USA 92093.

Largus californicus goes through striking ontogenetic color changes from red first instars to shiny black second through fifth instars to black and orange adults. The current utility of the various colors in relation to predator interactions, thermoregulation, and mating cues were examined with manipulation experiments. Lizards find the black nymphs distasteful and avoid further interactions. Two invertebrate predators, a spider and a bug, did not find the bugs distasteful. Although black instars absorb more light energy than red instars, behavioral thermoregulation, by clustering, probably affects body temperature more than light absorption differences in insects this small. The color differences between black nymphs and black and orange adults may be used by males as a mating cue.

CHEMICALS, A BETTER PROTECTION FOR CATERPILLAR SURVIVAL. Y.S. Chow*, and R.S. Tsai, Institute of Zoology, Academia Sinica, Taipei, Taiwan 11529, R.O.C.

In Taiwan, during the summer time we can find 2 types of eversible glands for defensive behavior in the lepidopterus larvae. One is the caterpillar of *Papilio memnon heronus* Frunstorfer with the gland in the front part of the head, whereas other is the larvae of puss moth *Dicranura* sp. with the eversible tube at the rear end. Although in response to irritation, the exocrine glands of these 2 species give exactly same bright-colored appearance, only the *Papilio* species emitted a strong smell. The characteristic intense odor was isolated and identified as isobutyric and 2-methylbutyric acid by GC and GC-Mass spectrometry. In a field experiment, only the *Papilio* larvae with the acid secretions can escape from the attack of hungry mantids *Tenodera aridifolia sinensis* Saussure, and most *Dicranura* larvae were eaten within 12 hours after release. In a field survey in 1987, the population of the *Papilio* caterpillar is higher than *Dicranura* population in natural condition. It is postulated that simple chemicals such as isobutyric and 2-methylbutyric acid are better defense than only the mechanical appearance for the insect survival in the evolutionary line of existence.

PSEUDOSTIGMATID DAMSELFLY PREDATION ON SPIDER PREY: FORAGING HABITS AND PREY "RISK ASSESSMENT." L.S. Rayor, Dept. Biological Sciences, University of Cincinnati, Cincinnati, Ohio, 45221, USA

Field study of a neotropical damselfly, *Mecistogaster modestus* (Pseudostigmatidae), in the rainforest of Costa Rica demonstrates that it preys exclusively on small, web-building spiders. The damselfly forages only in direct sunlight: either in persistent sunflecks or in gaps in the canopy. The major prey species build tangled, but non-sticky or sticky, but planar webs from which the resident spider can be plucked by the hovering damselfly with minimal risk to the damselfly of contacting sticky silk. Once a web has been located the damselfly returns repeatedly to attack the spider.

In 124 observed predation attempts *M. modestus* captured 63% of the spiders attacked. One spider species, *Modisimus* sp. C (Pholcidae), received 55% of the attacks, yet it avoided capture at a much higher frequency than that shown by the other spider species attacked. Evidence indicates that pholids surviving damselfly attacks may assess their future risks of predation.

EFFECT OF DEFENSIVE BEHAVIORS OF THE CITRUS BROWN APHID, *TOXOPTERA CITRICIDUS* (KIRKALDY) (HOMOPTERA:APHIDIDAE) ON THE OVIPOSITION SUCCESS OF ITS PARASITOID, *LYSIPHLEBUS JAPONICUS* ASHMEAD (HYMENOPTERA:APHIDIIDAE). M. Takanashi, Inst. Biol. Cont., Fac. Agr., Kyushu Univ., Fukuoka 812, JAPAN.

The citrus brown aphid responds to attack by the parasitoid in two different ways. First, the host ejects secretion like wax from its conicles in the instant of stabbing by the parasitoid. When the ejected liquid struck any part of the parasitoid body, it stopped attacking to clean up the part or retreated from the colony. Second, the host jerks up and swivels its body around its stylet inserted to avoid being stabbed (swivelling). In the result of laboratory experiments, the following four characteristics of the swivelling were observed: 1) the hosts in the same colony repeated swivelling continuously and synchronously; 2) Swivelling was sometimes induced by contact with the swivelled body of neighbor host in the colony without stabbing by the parasitoid; 3) With successive host ages, the number of host swivelled in a colony increased; 4) There was a negative correlation between the number of hosts swivelled in a colony and the proportion of successful oviposition by the parasitoid.

BENEFITS OF EGG-GUARDING BEHAVIOR OF A TROPICAL BUTTERFLY
HYPOLIMNAS ANOMALA. I.H. Schreiner* and D.M. Nafus.
College of Agriculture and Life Sciences, University of
Guam, Mangilao, Guam. U.S.A. 96923.

Egg guarding in butterflies is unique to the nymphalids Hypolimnas anomala and H. antilope. H. anomala lays eggs in large clutches which average 450-500 eggs. The female guards them until the larvae leave the site one or two days after hatching. Survival of the eggs and very young larvae increased from 35% to 61% when they were guarded. The primary mortality factor was ant predation. Butterflies were able to discourage the most common ant, Monomorium minutum, by beating their wings over the eggs. Survival of the eggs increased as a function of cluster size. In clutches smaller than 200 eggs only 20% of the eggs survived to hatch, whereas 60% of the eggs in larger clutches survived. Larvae aggregate through the fifth instar. The percentage of larvae surviving to the sixth instar increased linearly as the initial number in the group increased. Aggregations of larvae which started with fewer than 130 first instars had no survivors. If an average sized egg mass was not guarded, it would be expected that only 4 larvae would survive to the sixth instar, whereas for a guarded mass, 15 larvae would be expected to survive.

BEHAVIORAL ECOLOGY OF FORAGING BY PACHYDIPLAX LONGIPENNIS (ODONATA: LIBELLULIDAE). Joel M. Baird and Michael L. May* Department of Entomology and Economic Zoology, Rutgers University, New Brunswick, NJ 08903, U.S.A.

Food intake, prey availability, prey capture behavior, and aggressive behavior at feeding areas were studied in P. longipennis at Gainesville, FL, USA. Behavior was quantified by observations of focal individuals on artificial perches at varying densities. Prey availability was assessed visually and with sticky traps. Weather conditions and numbers of P. longipennis were monitored periodically. Prey capture success was high and relatively constant, but frequency of feeding flights depended on temperature, sunlight, prey density, and the density of other dragonflies. Prey density was highly variable; individual P. longipennis were attracted to localized prey concentrations. Both sexes, but especially males, initiated aggressive interactions; sexual interactions were usually absent. At least at low dragonfly densities, individuals appeared to defend territories. Near very dense prey concentrations, aggression declined as feeding activity became very intense.

THE ROLE OF THE 'HAIR-PENCILS' IN COURTSHIP BEHAVIOUR IN THE CABBAGE MOTH, MAMESTRA BRASSICAE (L.) (LEPIDOPTERA: NOCTUIDAE), WITH A REVIEW OF 'HAIR-PENCILS' IN NOCTUID MOTHS. Martin C. Birch* and Guy M. Poppy, Department of Zoology, South Parks Road, Oxford OX1 3PS, England.

The function of the male hair-pencils (HPs) in courtship was studied using normal males and males without HPs, in moving air conditions in a wind tunnel. HPs removal did not affect the overall courtship success of males. It is possible that HP volatiles act as an arrestant for the female both during courtship and, after pair formation, to increase female acceptance and to prevent premature termination of copulation.

It has been assumed that the male HPs in noctuid moths function in courtship, just like male brushes and coremata in other moth families. Previous results suggest an elaborate courtship ritual involving HPs in many species in different families, but the published research on noctuids does not support the view that HPs are definitely used in courtship. We will look at possible functions of this large male organ and explore the courtship and defence behaviours.

WHAT CONSTITUTES A SUCCESSFUL MALE IN DACUS DORSALIS HENDEL (DIPTERA, TEPHRITIDAE)? R. Poramarcom Hawaiian Evolutionary Biology Program, University of Hawaii Honolulu, Hawaii.

The mating behavior of Dacus dorsalis males was examined from two aspects: (1) their ability to attract females to their courtship arena, and (2) the amount of time they spend fanning wings and courting females.

Twelve pairs of mature virgin males and females were individually marked and placed in a cage. Each day, males were placed back into the cage and females were replaced with new virgin females. This test was continued until two males in each of four categories: zero, one, two and three-time maters were obtained. These males were used in the following experiments. First, 2 males of each category were placed singly in screened cages hung on a plant to attract females. Three-time maters were significantly better in attracting females than males of the other categories. In the second experiment, 1 male each of all categories were placed in an aquarium containing females confined singly in screened cages hung on a plant to monitor the amount of time males spent fanning wings. It is expected that three-time mated males will spend significantly higher amount of time in wing-fanning than males in the other categories.

REPRODUCTION BEHAVIOR OF THE GIANT LOOPER BOARMIA (ASCOTIS) SELENARIA SCHIFF. (LEPIDOPTERA: GEOMETRIDAE) D. Hadar* and M. Wysoki, Dept. of Entomology, ARO, Bet Dagan, Israel

Mating, fertility and fecundity of B. selenaria, an important pest of avocado were studied. Females were able to copulate only once at night even when 3 males were present, when new males were present every night, the females were able to mate twice during their life span. The change of sex ratio from 1:3 to 1:1 and 3:1 (female to males) decreased the mean number of copulations from 1.3 to 0.9 and 0.5 per female, respectively, and in the latter case to a drastic reduction of fertilized females (83% to 37%). After 2 days delay of male presence only ~ 50% females mated; oviposition was low (389 eggs per female) and most of the eggs were deposited after mating. Male moths usually mate only once a night but they mate repeatedly up to five ($\bar{x}$ 3.3) times during their life. Virgin females in traps hung in avocado orchards were attractive to males during the first 2 nights after emergence, less attractive on the third night, and almost unattractive thereafter, similar to traps baited with mated females. When the traps were baited with mated and unmated females together, no males were trapped at all. Marked males were released 500 m from virgin-female-traps, 19% of them were recaptured; males were trapped up to a 800 m.

BIOLOGICAL ASPECTS OF SEX PHEROMONE RESPONSE IN APHIDS. D.C. Griffiths, AFRC Institute of Arable Crops Research, Rothamsted Experimental Station, Harpenden, Herts., United Kingdom, AL5 2JQ.

It has been known for many years that sex pheromones are produced in the hind tibiae of oviparous aphids and detected by sense organs on the male antenna. However, only recently has an identification of the sex pheromone been achieved; in Megoura viciae it is a mixture of two monoterpenoids, nepetalactol and nepetalactone. The behavioural role of these compounds has been investigated.

The study has now been extended to other species of aphid. The same two compounds, in different proportions, are produced by oviparous Aphis fabae and Acyrtosiphon pisum and a strain of Schizaphis graminum imported from the United States. Possibilities for use of such compounds would be greatest in economically-important heteroecious species, possibly in combination with primary host-plant volatiles.

INTERSPECIFIC VARIATION OF SEX PHEROMONE ACTIVITY IN MALE COCKROACHES OF PERIPLANETA AND BLATTA.

S. Takahashi* and H. Takegawa, Pesticide Research Institute, Faculty of Agriculture, Kyoto University, Kyoto, 606 Japan.

To investigate the sex pheromone structure and activity relationship, activity of synthetic pheromones and extracts from females was bioassayed in the males of six species of genera Periplaneta and Blatta. The activity of synthetic ($\pm$)-periplanone-B was very high in the males of P. americana and low in the males of P. japonica, P. brunnea and B. orientalis. Other pheromones showed interspecific variation of activity among the males of the six species.

Attractivity of ($\pm$)-periplanone-B to the males of Periplaneta species was tested in houses at several locations. ($\pm$)-Periplanone-B in traps attracted P. brunnea and P. japonica in addition to conspecific P. americana.

EVOLUTION OF PHEROMONE CHANNELS OF COMMUNICATION: INTER- AND INTRAPOPULATION VARIATION OF THE USE OF IPSDIENOL BY THE PINE ENGRAVER, *IPS PINI* (SAY) (COLEOPTERA: SCOLYTIDAE). D.R. Miller* and J.H. Borden, Department of Biological Sciences, Simon Fraser University, Burnaby, British Columbia, Canada V5A 1S6.

Pine engravers, *Ips pini* (Say), use pheromone-based communication. Males produce the pheromone, ipsdienol. Both sexes of *I. pini* are attracted to ipsdienol, resulting in large breeding aggregations. Geographic variation in the pheromone channel used by *I. pini* is based on the relative proportions of the two enantiomers of ipsdienol: R-(-) and S-(+). We describe the pheromone channels for three populations of *I. pini* in British Columbia, breeding in lodgepole pine, *Pinus contorta* var. *latifolia* Engelm. Data on the production of and field response to chiral ipsdienol are used to describe each channel. Geographic variation in the production of chiral ipsdienol by male *I. pini* was clearly evident. However, similar geographic variation in the responses of both sexes of *I. pini* to chiral ipsdienol was not evident. Our data suggest that the two traits are not closely linked.

SMOKE EMISSION AND ITS MECHANISM OF MALE MELON FLY, *DACUS CUCURBITAE* COQUILLET (DIPTERA: TEPHRITIDAE). H. Kuba* and Y. Sokei, Fruit Fly Eradication Project Office, Okinawa Prefectural Government, 123 Maji, Naha, 902 Japan.

Male melon fly releases the sex-pheromone which attracts virgin females. Smoke emission from rearing cage with sexually matured males can be observed at dusk, the period associated with mating of this species. This smoke attracts virgin females. Therefore, the smoke must contain the sex-pheromone of male fly.

The smoke emitted by a single male can be visually detected by focusing a beam of light at the wing-vibrating male. It was emitted to front, rear and upper sides of the fly. Through the investigation of smoke emission mechanism, we found a new type of pheromone release behavior. The outline may be summarized as follows. When male melon fly engages in calling behavior, the sex-pheromone produced in the rectal gland is excreted from anus. This excretion is wiped-off with the tarsus of hind legs, and then it is attached to the sexual dimorphic wing hairs which grow in cubital cell. During the wing-vibration, the pecten which is peculiar to male and grows in the 3rd abdominal segment is rubbed with the wings. These behaviors are thought to be the sequences of the smoke emission.

THE ROLE OF FEMALE RESPONSE SONG IN BUSH CRICKET MATING BEHAVIOUR (ORTHOPTERA; TETTIGONIIDAE). David Robinson, Department of Biology, The Open University, Walton Hall, Milton Keynes, MK7 6AA, United Kingdom.

Female song has been recorded in a small number of species of bush cricket. In those species where it has been studied it has been found to be an essential feature of reproductive behaviour, since it brings the sexes together. However, in large numbers of species the sexes meet up without the female producing a calling song, so there must be some selective advantage for those species where the female sings. Singing could be seen as a disadvantage in species that are preyed on, since the movement involved in sound production, as well as the sound itself, could allow a predator to pinpoint its prey. There are a number of features of the mating systems found in ephippigerines and phaneropterines that suggest that female song may be an advantage where the individuals are flightless, or the population density is low.

ACOUSTIC BEHAVIOR OF THE EREMOGRYLLINE GRASSHOPPERS *EREMOGRYLLUS HAMMADE KRAUSS* AND *NOTOPLEURA SAHARICA KRAUSS* (ORTHOPTERA: ACRIDIDAE). Syriël A. Blondheim, Department of Zoology, Hebrew University, Jerusalem, 91904, Israel.

The minute size, cryptic appearance and self-burial habits of *E. hammadæ* stand in direct contrast to the self-advertisement resulting from the intensity, long duration and stridulatory leg movements of the calling song. The spacing of individual males in nature is better understood when considered against the background of nonstereotyped sounds emitted under conditions of close-range confrontation in laboratory cages.

Calling songs of *N. saharica* males vary in number and in arrangement of structural elements, but all are of great intensity.

The calling songs of both species, however variable at the outset, terminate in a 'coda' of chirps, variable in number, but uniform in structure.

An attempt is made to associate the elements of the acoustic behavior with the semi-desert environment in which both these species live.

THE (Z)-5-TETRADECENYL ACETATE/(Z)-7-TETRADECENYL ACETATE COMMUNICATION SYSTEM OF SOME NEW ZEALAND TORTRICIDAE (LEPIDOPTERA). S.P. Foster*, J.R. Clearwater, S.J. Muggleston and J.S. Dugdale, Entomology Division, D.S.I.R., Private Bag, Auckland, New Zealand.

In the Northern Hemisphere, closely-related members of the family Tortricidae commonly effect reproductive specificity by utilising sex pheromones consisting of different ratios of the geometric isomers, (E)-11- and (Z)-11-tetradecenyl acetates plus other biochemically-related components. In New Zealand, a closely related group of tortricid moths use a sex pheromone system based around the two positional isomers, (Z)-5- and (Z)-7-tetradecenyl acetates. Reproductive specificity of the species can generally be recognised by the ratios of the two components, although in most cases it is probably achieved by the addition of other components.

The chemical and behavioural work on the moths using this communication system is discussed.

THE ACOUSTIC COMMUNICATION IN SEVEN EUROPEAN BUSHCRICKETS: A COMPARATIVE STUDY. K. Kahrmring, Department of Zoology, Marburg, University, West Germany.

Communication requires an emitter, a transmission channel, and a receiver system. Tettigoniid species often live in very differently structured biotopes, therefore the conditions for the sound transmission from the emitter to the receiver can differ greatly. Hence one may expect adaptations in the emitter as well as in the receiver to the acoustic conditions in the biotope. Also the acoustic behaviour of the animals is expected to suit their conditions. Adult males and females of seven different bushcricket species have been chosen for a comparative study of their acoustic-vibratory communication. Song generation mechanisms, the transmission of the acoustic signals in the field as well as sound perception and processing in the central nervous system of the insects have been examined and will be presented here.

HOST SELECTION AND COLONIZATION BEHAVIOR OF THE MINUTE PINE BARK BEETLE, *CRYPHALUS FULVUS* NIJIMA (SCOLYTIDAE). M. Sasakawa and T. Sasakawa*, Laboratory of Entomology, Faculty of Agriculture, Kyoto Prefectural University, Kyoto Japan 606.

Cryphalus fulvus is one of the most destructive species of the Japanese red-pine, *Pinus densiflora* Sieb. et Zucc. It passes through three generations per year in Kyoto. Pioneer females land at random on healthy and weakened pine trees during the period of pre-aggregation flight. They fly at a height of about 4 m above ground level in and out of stand. Dispersal flight peak occurs between 25-34°C. Once she bores in a weakened tree without resin pressure mass attack is initiated on the tree, owing to her production of pheromone. Female in egg gallery recognizes his arrival through the male vertex-pronotal stridulation and ceases the secretion of pheromone. Optimum density of entrance holes is 700 -1,000 per square meter of bark. When the density exceeds optimum level, some of parental beetles escape from host, and females re-attack. Both male and female elytra-abdominal stridulations have a rivalry or territorial function. Chemo-acoustic interaction, therefore, plays a role in the colonization behavior.

BIOSYNCHRONICITY IN NATURE. H. F. Chu, Institute of Zoology, Academia Sinica. Beijing, 100080, China.

Biosynchronicity is the synchronous relationship both in time and in space of organisms in nature. If without biosynchronicity, the food web or food chain cannot be formalized. From asynchronicity may realize more about the importance of synchronicity. This paper consists of discussions on the following topics: synchronicity between host and parasite, interspecific synchronicity, synchronicity vs. asynchronicity, allopatric synchronicity, sympatric synchronicity, synchronicity interfered by ecological factors, sympatric but asynchronous, and biosynchronicity in practical applications. Under each topic, many interesting examples are given.

ARE BUMBLE BEES RISK-SENSITIVE FORAGERS?: A LAB STUDY.

Ralph V. Cartar, Dept. Biosciences, Simon Fraser Univ. Burnaby, B.C. Canada V5A 1S6

Previous work on bumble bee risk aversion did not consider handling times, so it is not clear that bumble bees are risk-sensitive foragers. Here, I re-address the question of bumble bee risk-sensitivity. I examined how the response of bumble bees to variation in nectar reward was affected by colony energy reserves, which I manipulated by draining or adding sucrose solution to colony honey pots. Nine workers from 4 confined colonies of *Bombus occidentalis* foraged for sucrose solution in 2 patches of artificial flowers. These patches yielded the same mean rate of net energy intake, but rewards were variable in one patch and constant in the other. My results show that under controlled laboratory conditions, bumble bees are both risk-averse (preferring constant flowers) and risk-prone (preferring variable flowers), depending on their colony energy reserves. I will discuss conditions under which this behavior is adaptive for increasing colony fitness.

EFFECTS OF HONEY BEES ON THE REPRODUCTION AND NEST BIOLOGY OF *EXONEURA ASIMILLIMA* RAYMENT (ANTHOPHORIDAE: CERATININI), AN AUSTRALIAN NATIVE BEE. E. A. Sugden* and G. H. Pyke, California Department of Food and Agriculture, Sacramento, California and The Australian Museum, Sydney, Australia.

Exoneura asimillima Rayment is a semi-social native bee that, in Nadgee Nature Reserve, nests in the dead flower scapes of a grass tree, *Xanthorrhoea concava* (A. Lee) Bedford. We categorized nests as either founder (newly formed; few adult females; no pupae or adult males) or established nests and compared the nest biology of this species in an experimental area into which honey bees were introduced and in a similar control area. The presence of honey bees apparently caused increased departure from established colonies of adult bees which then left the study site, died, or formed new founder colonies. The net effect of honey bees from the apiary was a reduction in the total numbers of adult male and female *E. asimillima* relative to the control area. Surprisingly, reproduction in founder nests was higher in the experimental area than in the control area, but this could have been due to the relatively experienced emigrants from already established colonies being able to reproduce more rapidly than naive foundress bees. Survivorship of established nests was not affected by nest type or the presence of honey bees.

THE USE OF ^{131}I AND ^{125}I AND AGGRESSIVE BEHAVIOUR TO DETERMINE FORAGING AREA OF *HODOTERMES MOSSAMBICUS* HAGEN (ISOPTERA). T.C. de K. van der Linde*, P.H. Hewitt and M.C. van der Westhuizen, Department of Zoology and Entomology, University of the Orange Free State, Bloemfontein 9300, Republic of South Africa.

Hodotermes mossambicus Hagen workers readily collected ^{131}I and ^{125}I -treated lucerne which was provided at feeding stations on the soil surface. Thereafter termites were collected at regular intervals and at predetermined distances from the feeding stations and counted. Booster feeding of ^{131}I , which has a half life of only eight days, was given at each feeding site every three weeks. The area of the foraging territories which were shown to vary between 0.5 ha and 2.0 ha could thus be ascertained.

Individuals collected from different foraging holes within the radio-isotope territory were not mutually aggressive, whereas individuals collected outside were aggressive towards individuals collected inside the radio-isotope territory. These results verified the validity of the radio-isotope experiments.

One month after termination of the experiments radiation at all the sites was well below accepted norms.

The implications of these results for bait control strategies are discussed.

ANTS AND SEED DISPERSAL IN THE CAPE FLORAL KINGDOM. J.H. Giliomee, Department of Entomology, University of Stellenbosch, 7600 Stellenbosch, South Africa.

Ants are involved in the dispersal of the seeds of more than 1000 species of the Cape Flora. They are attracted to the fruit bodies (elaiosomes) of these seeds and carry them to their nests where some of them germinate. According to the literature, this system is threatened by the introduced Argentine ant *Iridomyrmex humilis*, which displaces native ants and feeds on the fruit bodies without dispersing the seeds, thus affecting regeneration of the plants. However, in an experiment to verify this, the hypothesis was not supported. There was no difference between the rate of removal of seeds where *I. humilis* was present and where it was absent. In the area infested with *I. humilis* two native species, *Ocymyrmex barbigier* and *Tetramorium quadrispinosum*, were observed to remove seeds and transport them to their nests. *O. barbigier* carried seeds for up to 25 m to the nests.

Was the threat of the Argentine ant overestimated?

THE IMPORTANCE OF SOCIAL BEHAVIOR FOR *MALACOSOMA CALIFORNICUM FRAGILE*, A SUBSPECIES OF THE WESTERN TENT CATERPILLAR. W.P. Weaver Jr., Department of Biology, University of California, Los Angeles, CA 90024, USA.

Malacosoma californicum fragile (MCF) hatches unusually early in the spring, when the harsh weather of its mountain habitat makes it seemingly inhospitable for insects. Seasonal declines in food quality and dramatic increases in mortality due to parasitization probably select for this early emergence. Laboratory growth rate experiments established that MCF development is temperature dependent. An efficient system of chemical communication enables the caterpillars to minimize time spent feeding (exposed to natural enemies), while maximizing time spent within the colony's warm silk tent (where they can develop at a faster rate). Laboratory pheromone-removal experiments showed a decrease in growth rates with increasing complexity of environment. Field manipulation of egg masses demonstrated greater survivorship with increasing colony size. These results strongly imply that the social behavior of MCF larvae makes it possible for them to survive and develop rapidly, despite conditions very unfavorable for most insects.

ATTACHMENT, LOCOMOTION, AND SILK OF *SIMULIUM VITTATUM* ZETTERSTEDT (DIPTERA: SIMULIIDAE) LARVAE. W.B. Barr, Department of Entomology, University of Alberta, Edmonton, Alberta, Canada, T6G 2E3.

During attachment, larvae bent their bodies laterally. This lateral bending probably reduces drag on larvae by keeping their bodies in the weaker current close to the substrate. Nonetheless this lateral bending, common to larvae in related families, probably originated ancestrally in environments of little current. When attaching themselves to substrates and during locomotion, larvae produced artifacts of silk. Associating the shapes of these silken artifacts with structures of the larvae, and with behaviours of the larvae, resulted in better understanding of all three. The larvae did not eat their silk, but they did appear to conserve time, effort, and silk.

IMPORTANCE OF SEMIOCHEMICALS IN *DYSDERCUS CINGULATUS* (HETEROPTERA, PYRRHOCORIDAE) BEHAVIOR. J.P. Farine and C. Everaerts*, Laboratoire de Zoologie, UA CNRS 674, Université de Bourgogne, 21000 Dijon, France.

The behavior of *D. cingulatus* is divided in four parts (gregariousness, sexual behavior, alarm and defense); in all these, the exocrine secretions play a prominent part.

The role of the different identified compounds has been studied and analysed.

RECENT PROGRESS IN DEVELOPING A CONTROL PROCEDURE FOR ADULT CORN EARWORM, *HELIOTHIS ZEA* (BODDIE). P. D. Lingren*, J. R. Raulston and E. V. Wann, U. S. Department of Agriculture, Agriculture Research Service, Lane, Oklahoma 74555

Emergence behavior of adult corn earworms has been defined in corn fields and shows that adults emerge at night and immediately climb upon a vertical surface to expand and dry their wings. The adults stay at the emergence site for at least 2.5 hours before taking short flights. During this period they will feed, even within 2 minutes after exiting the pupal case. Flowers from plants of the genus *Gaura* and a 3:1 water-sorghum molasses mixture laced with 2% Larvin killed 100% of the moths that imbibed the liquid. Likewise, a formulation of sorghum molasses, water, and 2% Larvin (1 ml) placed in a band around corn stalks in field plots killed nearly 100% of corn earworm moths emerging from the plots.

SHORT TERM MEMORY AND PLASTICITY IN THE LOCUST FLIGHT SYSTEM. B. Möhl, Universität des Saarlandes, Zoologie, AG Nachtigall, D-6600 Saarbrücken, FRG

Flight motor output of the locust can be biased by immediate previous flight experience. For instance, when a tethered locust is subjected to a yaw stimulus for a few seconds of flight and then turned back into a straight forward direction, the motor pattern will maintain part of the asymmetry which was originally generated by the previous yaw stimulus.

Locusts can even be trained to produce certain (asymmetric) flight patterns using a 'biofeedback' control set-up which measures the time difference between the spikes of two contralateral depressor muscles in a flying locust and compares it to a reference signal given by the experimenter. A difference between the measured time relationship and the given reference value produces a yaw stimulus which turns the locust away from the normal (i.e. straight ahead) position. Locusts are able to restore their normal position by adjusting activity of both flight muscles according to the reference value. Thus, the locusts reconstitute normal (exteroceptive) sensory feedback (straight ahead), whilst the motor output is constantly biased as prescribed by the experimenter (via the reference value). Certain experiments suggest that this plasticity of the flight system is basically due to proprioceptive control.

A VIDEO STUDY OF HOUSE-FLY FLIGHT BEHAVIOUR NEAR AN INSECT ELECTROCUTOR TRAP. P.R. Syms, A.E. Roberts* and L.J. Goodman, School of Biological Sciences, Queen Mary College, University of London, Mile End Road, London E1 4NS, United Kingdom.

The behaviour of house-flies, *Musca domestica* L. near a U-V electrocutor trap was monitored using video. Two closed circuit television cameras were used, one filming vertically 3.0m beneath the trap and another filming horizontally 3.0m from the side of the trap. These sequences were recorded on U-matic and VHS recorders. Approximately 300 flies were released into a white sealed room (dimensions 4.0m x 2.75m x 2.75m, density 10 per m³). The results show three distinct behaviour patterns, i) a neutral response, ii) a landing response on the trap, and iii) avoidance. The latter response constitutes almost half the flies tracks observed while only a small proportion landed on the trap. The data suggests an investigative response by the flies coupled with an avoidance response to certain trap features. It may be that an airborne survey of the trap is a necessary precursor to landing behaviour. Thus flies observed as avoiding the trap may later land, so the same fly may be filmed on different occasions. This would explain the high number of avoidance tracks and is consistent with the high rate of catch in these conditions.

DOES RESOURCE ALLOCATION IMPROVE THE FLIGHT POTENTIAL OF SURVIVING ADULTS FOLLOWING PERIODS OF LARVAL STARVATION? Jeremy N. McNeil*, Département de biologie, Université Laval, Ste. Foy, P.Q. Canada, G1K 7P4 and T. Casey, Department of Entomology, Rutgers University, New Brunswick, N.J., U.S.A.

Antennal length, femur length, wing surface area, ovipositor wide and endophallus length were examined in function of body mass for the true armyworm *Pseudaletia unipuncta*. The data obtained did not support the idea of geometric scaling. Smaller individuals had lower wing-loading than larger individuals. As it has been suggested that such a non-geometric relationship is adaptive, facilitating movement out of an unsuitable habitat by reducing the cost of flight, we compared several indices of flight performance of large and small adults. Data obtained on wing beat frequency and thoracic temperatures provide no evidence to support the hypothesis that a reduction in wing loading due to selective resource allocation would improve flight performance.

GENETIC AND ENVIRONMENTAL FACTORS INFLUENCING PRE-CALLING PERIOD AND THE MIGRATORY STRATEGY OF THE ORIENTAL ARMYWORM, *MYTHIMNA SEPARATA* WLK. (LEPIDOPTERA: NOCTUIDEA).
E. Han*, A.G. Gatehouse, School of Animal Biology,
University College of North Wales, Bangor, Gwynedd LL57
2UW, U.K.

Substantial variation in pre-calling period (emergence to first call) was observed in adult female *M. separata* moths. Two lines were established in a selection experiment by inbreeding in the first generation of selection - an early-calling (EC) line calling on nights 2-4 (mode value) and a late-calling (LC) line calling on nights 6-9. Reciprocal crosses were carried out in the 6th generation and the results provide evidence of a sex-linked major gene effect determining the onset of calling in female offspring. Pre-calling period was extended at low temperatures and by decreasing photoperiod from the pre-pupal stage to adult emergence. Larval density had no effect. Some EC, but no LC females were able to achieve oocyte maturation without feeding. Flight capacity, expressed as tethered-flight duration in the scotophase was reduced in females which had called compared with others of equivalent age which had not. These results are discussed in relation to the regulation of migration and to the migratory strategy of the oriental armyworm moth.

#1

AN INVESTIGATION OF THE LIMITS OF GROUND MOVEMENT DETECTION IN *HELIOTHIS ARMIGERA* (LEPIDOPTERA:NOCTUIDAE) DURING FLIGHT AT LOW ILLUMINATION LEVELS. C.M. Addison, Department of Pure & Applied Biology, Imperial College, Silwood Park, Ascot, Berks, SL5 7PY, U.K.

Radar studies have shown that nocturnally migrating insects flying at heights exceeding 300m adopt collective off-wind headings. One possible mechanism to explain this phenomenon is that insects use visual clues. We have tried to establish whether these insects make course corrections to ground pattern movement at the low illumination levels and angular velocities at which the orientation phenomenon has been observed in the field.

The insect is suspended from a torque meter in a flight simulation chamber and flies above a screen onto which is back projected a ground pattern. This has a forward component generated by a moving striped film loop, and a lateral component generated by a reversible striped slide. A microcomputer controls speed and direction of both components and records the output from the torque meter. Angular velocities down to 1s^{-1} and illuminations down to $1 \times 10^{-4} \text{ Wm}^{-2}$ (starlight) can be displayed.

#2

EGG HATCHING RHYTHMS IN THREE SPECIES OF LONGHORNED GRASSHOPPERS (ORTHOPTERA:TETTIGONIIDAE). T. Arai, Lab. of Biotechnology, Fac. of Education, Ashiya Univ., Ashiya, Hyogo, Japan 659.

The egg hatching rhythms in *Metrioptera hime*, *Gampsocleis buergeri* and *Homorocoryphus jezoensis* were observed under various conditions of photoperiod and thermoperiod. Their hatching responds to those conditions were about the same and suggested the similarity of time measuring mechanisms triggered by lights-on, -off, temperature rise and fall. But the continuity of hatching rhythms differed among the three species when the eggs were transferred from periodic conditions to constant ones. The hatching rhythm of *M. hime* did not continue. That of *H. jezoensis* indicated a clear circadian rhythmicity. In this respect, *G. buergeri* was intermediate between *M. hime* and *H. jezoensis*. These observations suggest either that the egg hatching time is controlled by different mechanisms in the three species or that hatching basically depends on the circadian rhythm with different of persistence.

#3

APOSEMATISM AND MIMICRY AMONG SOME OEDIONYCHINA (CHRYSOMELIDAE, ALTICINAE). A. Begossi* & W. W. Benson. Depto. de Zoologia, IB, UNICAMP, 13081, Campinas, SP, Brazil.

An important line of defense in flea beetles is their jumping ability. Some Oedionychina also present typical aposematic traits, such as slow flight, conspicuous colors and a tendency to aggregate. Since aposematism is often associated with unpalatability this study was undertaken to evaluate the acceptability of the oedionychines *Homophoea octoguttata*, *Alagoasa areata* and *A. cf. pantina* to naive captive predators. Male chicks (*Gallus gallus*) from 6 to 17 days old were fed on standard ration for 3 days before an experiment. The beetle *Tenebrio molitor* was used as the palatable control insect. Beetles were offered to chicks through a glass tube adapted to the chick cages. In each trial a predator was observed during two minutes and its response to the beetle recorded as not touched (NT), pecked (P) or eaten (E). Percent of rejection was calculated by the formula $100P/(P+E)$. All controls were eaten by chicks. Rejection in *H. octoguttata* was 72%, in *A. areata* 56% and in *A. cf. pantina* 44%. The similar appearance of these flea beetles, their occurrence in the same habitat and unpalatability indicate that they can be part of a Mullerian mimicry ring.

#4

GENETIC COMPONENTS OF FORAGING BEHAVIOR IN ADULT FLIES (DIPTERA: DROSOPHILIDAE, MUSCIDAE). William J. Bell, Department of Entomology, University of Kansas, Lawrence KS 66045 USA.

Adult *Drosophila melanogaster* and *Musca domestica* search near the site of a resource after ingestion, until after a certain length of time they take flight. Both the pattern of searching and the search duration are determined in part by an individual's genotype. The phenotype is also influenced by resource quality and quantity, patch cues, level of deprivation of the flies, and the presence or absence of predators or interfering individuals.

#5

BEHAVIORAL STUDIES WITH THE LEAFMINER PARASITE, *DIGLYPHUS BEGINI* (ASHMEAD) (HYMENOPTERA: EULOPHIDAE). J.A. Bethke*, K.M. Heinz and M.P. Parrella, Department of Entomology, University of California, Riverside, CA 92521.

The parasite, *Diglyphus begini*, has been used effectively in inundative releases into commercial chrysanthemum and marigold production for control of the leafminer, *Liriomyza trifolii* (Burgess). In an effort to better understand why these successes have occurred and to refine the system so that the numbers in a release and frequency of releases can be better defined, behavioral studies with *D. begini* were initiated. Adults spent more time searching on a chrysanthemum leaf with a live leafminer larva compared with leaves with parasitized larvae, dead larvae, empty mines or no mines. The number of encounters with potential hosts was highest on leaves containing live larvae than those with dead or parasitized larvae. Handling time was the reverse of this trend with less time on live vs. dead or parasitized larvae. *D. begini* attack behavior was strongly influenced by slight variations in the size of third-instar larvae.

#6

OVERWINTERING MICROHABITAT SELECTION BY AN ENDOPARASITOID THROUGH HOST BEHAVIOUR MODIFICATION. J. Brodeur* and J.N. McNeil, Département de Biologie, Université Laval, Québec, Canada G1K 7P4.

Aphidius nigripes (Aphidiidae), a common endoparasitoid attacking the potato aphid, *Macrosiphum euphorbiae*, has a facultative prepupal diapause within the mummified host. Parasitised aphids behave differently from unparasitised ones, and their behaviour will vary in function of the physiological state of parasitoid. Just prior to mummification aphids containing parasitoids destined to enter diapause leave the plant and select a non-exposed habitat to mummify. Those containing non-diapausing parasitoids remain on the plant. Before death aphids containing diapausing parasitoids exhibit negative phototaxis and positive thigmokinesis. We hypothesise that host behaviour modification will result in overwintering parasitoid being concentrated in protected areas where the actions of adverse weather conditions and natural enemies will be reduced. We tested this prediction using *Asaphes vulgaris* a Pteromalid hyperparasitoid of *A. nigripes*. The incidence of hyperparasitism was significantly lower for mummies containing diapausing rather than non-diapausing parasitoids.

#7

ADAPTIVE DISTRIBUTION OF ENDOPARASITOID MUMMIES THROUGH HOST BEHAVIOUR MODIFICATION. J. Brodeur* and J.N.McNeil, Département de Biologie, Université Laval, Québec, Canada G1K 7P4.

Field and greenhouse observations suggest that *Aphidius nigripes*, the principal endoparasitoid of the potato aphid, *Macrosiphum euphorbiae*, in north eastern North America has the ability to modify host behaviour which result in the selection of suitable mummification sites. While the majority of non-parasitised *M. euphorbiae* are located on the under surface of potato leaves (the preferred feeding area) 66% of parasitoid mummies were found on upper surface of leaves. Early in the season there was 50% survival of mummies on upper leaf surfaces compared with 26% on the under surface of leaves. This difference decreased as the overall incidence of hyperparasitoids increased throughout the season, giving overall means of 31.4 and 20.0% respectively. We hypothesise that by leaving the aphid colony parasitoid move from the usual foraging habitats of their natural enemies. Furthermore, in the upper canopy temperature are generally higher and exposed mummies passively thermoregulate, thereby reducing the duration of pupal development and time exposed to attack by hyperparasitoids.

#8

DISCOIDAL PATTERN OF AGGREGATION AMONG THE DEVELOPING GRUBS OF A TORTOISE BEETLE, *ASPIDOMORPHA MILIARIS* (CHRYSOMELIDAE: COLEOPTERA).

APURBA KUMAR CHATTOPADHYAY*, Department of Zoology, Burdwan Raj College, Burdwan, WB, India & NIRMAL CHANDRA SUKUL, Department of Zoology, Viswa Bharati University, Santiniketan 731 235, WB, India.

The immature stages of a tortoise beetle, *Aspidomorpha miliaris* aggregate in the form of a disc which may consist of a single ring or of two concentric rings. Aggregation is seen only during resting periods. During feeding the larvae arrange themselves in a linear fashion. All the members of a cluster react synchronously by moving the tip of their cast cuticle forward to any object approaching them thereby simulating a giant spider. The grubs appear to evade predators by a sort of cooperative mimicry.

#9

TERRITORIAL BEHAVIOUR OF THE BUTTERFLY *SANDIA XAMI* (LYCAENIDAE).

C. Cordero M. and J. Soberón M. Departamento de Ecología, Instituto de Biología, UNAM, México, Males of the butterfly *Sandia xami* perch in and defend particular areas with well defined topographic limits. These areas usually lack both larvae or adult resources. One individual defend the same territory an average of 5h/day, up to 23 days. The same areas are used as territories by different males on different occasions. These areas share some characteristic features which are described. Evidence is presented in support of the hypothesis that the territories function as mating stations. A possible scenario for the evolution of this territorial system is advanced.

#10

THE OVIPOSITIONAL BEHAVIOR OF POPULATIONS OF *EDOVUM PUTTLERI* [HYMENOPTERA: EULOPHIDAE] REARED ON DIFFERENT HOST SPECIES. J. E. Corrigan*, J. H. Lashomb, Dept. of Entomology, J. B. Smith Hall, Cook College, Rutgers University, New Brunswick, N.J. U.S.A. 08903.

Populations of *Edovum puttleri*, were reared on *Leptinotarsa decemlineata*, and *L. texana*. Females from each host were individually exposed to egg masses of *L. decemlineata* containing twenty eggs and their ovipositional behavior was recorded. These behaviors were compared for parasitoids reared from the two host species. The frequency and distribution of the components of ovipositional behavior were significantly different for parasitoids produced from the different host species. These differences are attributed to the host species on which each parasitoid type was reared.

#11

SEXUAL DIFFERENCES IN FLIGHT AND THERMOREGULATORY BEHAVIOR OF *EUPHYDRYAS PHAETON* (LEPIDOPTERA: NYMPHALIDAE). G. W. Gilchrist, Program in Ecology and Evolutionary Biology, Brown University, Providence, RI 02912. (Present address: Department of Zoology (NJ-15), University of Washington, Seattle, WA 98195).

Male *Euphydryas phaeton* butterflies are capable of flight at body temperatures 4-6°C lower than those of females. Basking females, however, are better able to maintain elevated body temperatures against short-term environmental fluctuations. These differences in thermoregulatory capacity are correlated with sex differences in body size and are consistent with the predictions of simple thermodynamical models. Females' flight may be more constrained by marginal weather conditions than the flight of males. I show that this constraint is reflected in qualitative differences in the flight ability of males and females rather than in quantitative differences in the amount of time available for flight. I propose that, for this species, behavior and morphology interact to yield functionally equivalent flight spaces.

#12

THE FEEDING BEHAVIOR OF THE LARVAE OF CABBAGE LOOPER, *TRICHOPLUSIA NI* (HÜBNER) (LEPIDOPTERA: NOCTUIDAE): INFLUENCE OF CHEMICAL MODIFICATIONS DURING GROWTH OF THEIR HOST-PLANT.

C. Guertin*, P.J. Albert, Department of Biology, Concordia University, 1455, De Maisonneuve Blvd. W., Montreal, Quebec, Canada H3G 1M8.

The feeding activity of larvae of the cabbage looper, *Trichoplusia ni* (Hübner) induces changes in the chemical composition of their host-plant (stress responses). Four different compounds - tannin, amino acid, sugar and wax - were used to evaluate these modifications.

The evaluation of the relation between deterrent and phagostimulant products in the plant may play an important role in the utilization (including consumption) of the host-plants. This study presents the results of the evolution in the pattern of feeding behavior of different instars, in relation to the variation in the phytochemistry of their host-plant.

#13

GUSTATORY DISCRIMINATION OF PLANT SAPS BY THREE LEPTINOTARSA SPECIES (COLEOPTERA: CHRYSOMELIDAE).

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Responses of galeal gustatory sensilla to plant saps are compared among three Leptinotarsa species. Leptinotarsa decemlineata, L. haldemani and L. texana show qualitatively similar electrophysiological traces for Solanum saps while responses to Lycopersicon esculentum are much more complex. The sensory basis for host plant - insect interactions is discussed in relation to observed chemosensory activity.

#14

THE BALL ROLLER SCARABS THAT DON'T ROLL. G. Halfpfer* and V. Halfpfer, Instituto de Ecología, Apartado Postal 18-845, Deleg. Miguel Hidalgo, 11800 México, D.F., México.

The principal feature of dung-beetles is the rapid relocation of a highly perishable food resource: excrement or carrion. Relocation is accomplished by burying food at different levels below the food source by burrower scarabs (vertical relocation) and at different distances by ball-rollers (horizontal relocation). The same ecological constraints and responses operate in nidification. The tribe Scarabaeini includes scarabs performing horizontal relocation by shaping a ball within the food source which is rolled and shallow-buried. This is the regular procedure followed by most species for feeding, and always for nesting. Non ball-makers or deficient rollers Scarabaeini have been reported. However, with the only exception of the Australian Cephalodesmus, nesting behavior is unknown and feeding behavior is poorly known.

Feeding and nesting behavior of Canthon obliquus are reported here. C. obliquus is a paleoendemism of the southern end of Baja California. It makes no food balls, only a smaller number of nesting balls, which are buried at once below the pad with no horizontal relocation. This is a new nesting behavior for a Scarabaeini species resulting in morphological changes. This behavior and changes are discussed in the light of its evolution in old isolation.

#15

THE BEHAVIORAL REPERTOIRE OF MATED FEMALE HESSIAN FLIES: IS IT REALLY SO LIMITED? M.O. Harris, Department of Entomology, Kansas State University, Manhattan, Kansas, U.S.A. 66506.

Egg-laying behavior of the Hessian fly, Mayetiola destructor (Diptera: Cecidomyiidae), as measured in simple no-choice bioassays, appears to be highly indiscriminant. Because of this, many researchers have concluded that accurate placement of eggs depends more on synchronization of fly emergence with suitable host plants rather than highly developed sensory and motor capabilities.

By considering effects of time-dependent responsiveness and precisely quantifying behavioral responses to host and non-host grasses, we have found that discrimination does occur at several, hierarchical, patch levels. In the first hours of egg-laying, females entering host plant patches exhibit high frequencies of putative examining behaviors (antennation and arching of abdomen with terminal segment contacting leaf surface). Females entering patches of non-host grasses exhibit lower frequencies of examining behaviors and show stronger phototactic responses. However, several hours later, females in non-host patches show increasing responsiveness to vegetative stimuli, and upon contacting foliage, exhibit higher frequencies of examining behaviors. These "deprived" females also show higher rates of egg-laying.

#16

INTERPOPULATIONAL VARIATION IN THE REDUNDANT PHEROMONE BLEND OF THE CABBAGE LOOPER MOTH, TRICHOPLUSIA NI (HUBNER) (LEPIDOPTERA: NOCTUIDAE). K. F. Haynes* and R. E. Hunt, Department of Entomology, University of Kentucky, Lexington, Kentucky, U.S.A. 40546.

Volatiles emitted from the exposed sex pheromone gland of female cabbage looper moths were analyzed by gas chromatography-mass spectrometry. Populations originating from field-collected females from Kentucky, California, and Florida showed little variation in the blend ratios of six pheromone components. Females from a laboratory population emitted blend ratios of pheromone components that were very similar to those emitted by females from field populations. However, the ratio of (Z)-5-dodecenyl acetate to (Z)-7-dodecenyl acetate was somewhat higher and more variable in females from the laboratory population. The apparent redundancy in the pheromone blend may allow effective communication throughout the geographic range of the species without the need for local adaptations for reproductive isolation.

#17

FEEDING BEHAVIOR OF PIEZODORUS HYBNERI GMELIN (PENTATOMIDAE, HETEROPTERA) ATTACKING SOYBEAN IN JAPAN. T. Hidaka, Division of Entomology, National Institute of Agro-Environmental Sciences, Tsukuba, Ibaraki, 305, Japan.

Piezodorus hybneri is one of the important pests of soybean plants and distributed widely from the temperate to tropical Asia. Feeding activity in the nymphal stages of the insect was studied for analyzing cause of damage. It is clarified that a peak of feeding times was seen at 3 days after moulting, feeding times clearly increased from the 2nd to the 5th instar, body weight was closely related to the feeding times, and a nymph attacked 57.72 soybean seeds in the average at 25°C. The feeding activity of the insect on soybean, clover, and artificial diet was also investigated by using the electronic insect feeding measurement (EIFM). The results obtained from the EIFM will be discussed.

#18

FUNGAL VOLATILES AS OVIPOSITION ATTRACTANTS FOR THE YELLOW PEACH MOTH, CONOGETHES PUNCTIFERALIS (GUENÉE) (LEPIDOPTERA: PYRALIDAE) H. Honda*, T. Ishiwatari and Y. Matsumoto, Department of agro-biology, University of Tokyo, Tokyo 113, Japan.

Attraction and oviposition responses of the yellow peach moth to 8 species of fungi were investigated in laboratory and field cages. The females were attracted to and oviposited on fruits of the codling, a host plant. The attractancy disappeared from a fresh codling fruit by dipping it in ether, but higher attractancy reappeared subsequently when the fruit was inoculated with fungi. Similar attractancy was observed on a mouldy rice cake. By contrast, a rotten codling or rice cake, infested with bacteria rather than fungi inhibited oviposition by the moths. From the mouldy codling or rice cake, 4 fungi (Penicillium sp., Cladosporium sp., Aspergillus fumigatus and Mucor sp.) were isolated. When grown on Czapek's medium, the first two species showed the highest attractancy, while the last two species were less attractive. Among 4 phytopathogenic fungi tested, Endothia parasitica and Alternaria solani were also attractive. By addition of α -ketoglutaric acid to the medium, attractancy of Penicillium sp. more increased. In a field cage, the females oviposited significantly more on the oviposition substrate baited with Penicillium sp. than on a fresh codling or unbaited control.

#19

HOST EGG KAIROMONES; AN OVIPOSITION STIMULANT FOR THE EGG-LARVAL PARASITOID, *ASCOGASTER RETICULATUS* WATANABE (HYMENOPTERA: BRACONIDAE). Y. Kainoh¹†, S. Tatsuki¹, H. Sugie² and Y. Tamaki², ¹Institute of Agriculture and Forestry, University of Tsukuba, Tsukuba, Ibaraki 305, Japan, ²Division of Entomology, National Institute of Agro-Environmental Sciences, Tsukuba, Ibaraki 305, Japan.

Both external and internal kairomones were essential for the oviposition of *Ascogaster reticulatus* Watanabe, an egg-larval parasitoid of the smaller tea tortrix, *Adoxophyes* sp. (Lepidoptera: Tortricidae). The external kairomone, needed for host location and acceptance, was extracted with 70% ethanol and the internal kairomone, needed for egg deposition, was extracted with water. The internal kairomone was identified as a mixture of several amino acids by using an artificial egg with Parafilm membranes combined with chemical analyses. Among amino acids detected in the host materials, alanine, arginine, glycine, histidine, isoleucine, leucine, methionine, proline, serine, tryptophane, valine were active. The mixture of these active amino acids was as active as the egg-mass-homogenate at the same ratio and concentration, suggesting that the most important component as the kairomone in a host egg is a mixture of several amino acids.

#20

ACTINIDINE SECRETING ROVE BEETLES (STAPHYLINIDAE). K. Kanehisa, Institute for Agricultural and Biological Sciences, Okayama University, Kurashiki 710, Japan.

When disturbed, certain rove beetles secrete defensive substances from specific glands. There are phylogenetic rules which govern the gland sites and components. Beetles of Staphilininae possess a pair of tergal pygidial eversible glands and revolve the abdomen against the attacker. Most secreted substances were genus specific; few were species specific.

Actinidine has been isolated and identified from the medicinal plant *Actinidia polygama* and is known to be a strong stimulant for Felidae, such as cat and lion, to have low volatility and to have bitter taste for man. *Phylonthus* (more than 20 species examined), *Caffius* and *Phucobius* secreted it as a main component. *Staphilinus*, *Creophilus*, *Ocypus* and *Quedius* secreted it as a minor component. *Algon grandicollis*, a Staphilininae and highly odoriferous species seemed to be species specific in secreting *n*-hexanoic acid, *n*-hexanal and (Z)-2-hexenal as a mixture.

#21

COMPARISON OF THE HOST-LOCATION BEHAVIOUR OF THREE SPECIES OF *COTESIA* (=APANTELES) (HYMENOPTERA: BRACONIDAE) WHICH ATTACK LEPIDOPTEROUS HOSTS ON BRASSICA. M.A. Keller, Department of Entomology, Waite Agricultural Research Institute, Glen Osmond, S.A. 5064, Australia.

The host-location behaviour of individual female *Cotesia rubecula*, *C. glomerata*, and *C. plutellae* are being investigated in laboratory assays, a flight tunnel, and the field. Differences among parasitoids are being examined to determine their influence on rates of parasitism. The goal of this study is to identify behavioural traits which characterize effective biological control agents.

#22

HOST FLOWERING PHENOLOGY AND OVIPOSITION DECISIONS BY THE THISTLE SEED FLY, *Orellia ruficauda* (FAB.) (DIPTERA: TEPHRITIDAE). R.G. Lalonde, Department of Biological Sci., Simon Fraser University, Burnaby, B.C., Canada V5A 1S6

Adult female *Orellia ruficauda* selectively oviposit into female thistle flower heads which are in the initial stages of blooming: a susceptible period of 1.5–2 days in duration. As the season progresses, the number of heads available for oviposition on a plant first increases and then slowly decreases, while the proportion of heads encountered by the flies that are susceptible steadily decreases as the inflorescence matures. A stochastic computer simulation model was employed to determine how optimal oviposition strategies may change with the season. Computer-generated distributions of eggs were compared with field distributions sampled at different times in the season as a partial validation of the model.

#23

HOST DISCRIMINATION BY *CHRYSOCHARODES* N.SP. (EULOPHIDAE), A PHORETIC EGG PARASITOID WASP OF *MECISTOMELA MARGINATA* THUNBERG, 1821 (CHRYSOSELIDAE). M.V. Macêdo. Dept. de Ecologia, I.B., Universidade Federal do Rio de Janeiro, CP 68020 CEP 21941, Rio de Janeiro, Brazil.

This study was conducted on Arraial do Cabo sand dunes, State of Rio de Janeiro, Brazil. We observed 30 beetle mating pairs, 20 adult females and 30 adult males. In the mating pairs only the females had wasps ($\bar{x}=3.73\pm2.03$; number of wasps ranging from 0 to 8). The mean number of wasps on these females was significantly different ($t=5.01$; $p<0.001$) from that on females of the adult female group ($\bar{x}=1.25\pm1.07$; number ranging from 0 to 3). As to the adult male group, only two individuals had wasp, only one on each. All the phoretic wasps found on the beetles were females. It was also verified that mating females taken to the laboratory laid their first egg within 1–5 days, while the ones found alone laid no eggs. However this feature needs to be investigated better. These observations suggest that the process of host discrimination may be based on kairomones (sexual pheromones) released by female beetles, in large quantities for copulation. The selective advantage of this behavior is evident since mating females have a greater probability to lay eggs and tend to do this sooner than single females.

Financial support came from FINEP and CNPq.

#24

FLIGHT-TUNNEL RESPONSES OF MALE *TRICHOPLUSIA NI* (HUBNER) TO MINOR SEX PHEROMONE COMPONENTS. R.W. Mankin* and M.S. Mayer, Insect Attractants, Behavior and Basic Biology Research Laboratory, USDA, Agric. Res. Service, P.O. Box 14565, Gainesville, FL 32604.

Adult male *T. ni* respond sexually when they are exposed to high-concentration plumes of their minor sex pheromone components in a flight tunnel. The percentages of males performing specific behaviors and the durations of these behaviors differ from those of males exposed to female glands. These behaviors are interesting from a neurophysiological perspective because recordings from two types of pheromone receptor neurons on *T. ni* antennae have shown that the neural response specificity decreases at high concentrations. The behavioral and neurophysiological results indicate that high concentrations of the minor components can stimulate all the neurons that respond to the complete blend and elicit copulatory responses. It is clear that the blend is not being mimicked, because the responses to the minor components differ qualitatively from the responses to the female glands; nevertheless, a complete sequence of sexual response often can be elicited.

#25

OVIPOSITION AND FEEDING BEHAVIOUR OF THE PEA BLUE, LAMPIDES BOETICUS L. (LEPIDOPTERA: LYCAENIDAE) ON THE LABLAB BEAN. Y. Matsumoto* and H. Honda, Department of Agrobiological Science, University of Tokyo, Tokyo 113, Japan.

Gravid females selectively oviposited on the young flower buds which were diets suitable for the younger larvae. They attacked exclusively the anthers in the flower buds, whereas the older larvae were found in flowers or pods. With an agar disc assay, 80% MeOH extracts from immature pods of the lablab bean revealed a positive phagostimulancy to the larvae but neither ether nor chloroform extract did. Only binary mixture of neutral and amphoteric-basic fractions from the 80% MeOH extract showed a phagostimulating activity. Three sugars and 9 amino acids in pods were identified. Glucose and fructose increased their activities when they were provided in mixture. L-valine and L-alanine showed merely slight phagostimulancy but the other were inactive. When the binary mixture of the sugars was further added to amino acids, the synergistic phagostimulancy increased drastically, particularly in the multi amino acids mixtures. Maximum synergistic phagostimulation was obtained with the mixture consisting of glucose and fructose in 200mM, and L-valine, L-alanine, γ -aminobutyric acid and L-proline in 20mM.

#26

FORAGING BEHAVIOR OF AN ANTLION LARVA, MYRMELEON BORE IN RELATION TO THE FEEDING RATE.

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Myrmeleon bore is a pit-building antlion which lives in the open sand dunes. They change their pits with relatively high frequency in the habitat. Laboratory experiments were conducted to examine whether feeding level of the larvae influences their pit relocation rate.

Eight antlions were released into each of 6 boxes filled with sand. I divided the sand surface of each box into two half areas, then gave prey to the pits built in a half area and gave no prey to the pits built in the other half. During the 50-day observation period, nonfed antlions never moved into the area where prey were given.

Next, the 3rd instar larvae were reared separately without food. Even under starved conditions they rarely relocated their pits until death. The average duration of survival period was 84 days.

The experimental results indicate that M. bore larvae exhibit low movement rates which are independent of prey capture rates. Pit relocation of these larvae in their natural habitat is due to other factors such as heterogeneity of sand water content among microhabitat.

#27

THE GROUP EFFECT IN ACHETA DOMESTICUS (L.) (ORTHOPTERA: GRILLIDAE). J.E. McFarlane, Department of Entomology, Macdonald College, Ste-Anne-de-Bellevue, P.Q. Canada H9X 1C0

The group effect in A. domesticus is the faster growth of larvae reared in groups of two or more as compared with individually reared larvae. The group effect is really an effect of isolation, as the grouped condition seems to be the normal one.

The group effect is age and sex dependent, but does not appear to be influenced by excreta or by the nutrition of the insect.

The mechanism of the group effect is not understood, but there is evidence for the transfer of a lipid material from the cuticle via contact with the tarsi to the hemolymph of the receiving individual.

#28

OVIPOSITIONAL BEHAVIOR OF THE ONION FLY, DELIA ANTIQUA - VIDEOTAPE PRESENTATION. J. R. Miller* and T. M. Mowry, Department of Entomology and Pesticide Research Center, Michigan State University, East Lansing, Michigan 48824, U.S.A.

Onion fly preovipositional examining and actual egg depositional behaviors in response to defined artificial onions were videotaped close-up using specially developed apparatus allowing viewing of both above- and below-ground events. Before laying, this specialist herbivore proceeds through a series of "substrate runs" and "stem runs" during which examining occurs via tarsi, mouthparts, antennae, eyes, and ovipositor. Flies progress to soil-probing with the ovipositor; but they punctuate this terminal behavior with reiterations of the early steps. Once an egg is moved to the bursa copulatrix, it is invariably laid in a manner highly reproducible within and across individuals; thus, egg deposition is much more stereotypic and catenary than is examining. In addition to presenting actual behavioral sequences, this videotape presentation covers methodologies and quantitative data characterizing D. antiqua oviposition.

#29

THE FUNCTION AND SOURCE OF THE SCENT IN THE PIGMY MOLE CRICKET, TRIDACTYLUS JAPONICUS DE HAAN, (ORTHOPTERA: TRIDACTYLIDAE). N. Moriya and T. Ichinose, Laboratory of Applied Entomology, Faculty of Agriculture, Tokyo University of Agriculture and Technology, Fuchu, Tokyo 183, Japan.

When pigmy mole crickets are picked up they often discharge a characteristic scent. We believed that this scent was a defensive weapon against predators and performed some experiments to confirm this idea.

Two groups of crickets, one which discharged the scent when held by human fingers prior to the experiment, and the other which was not held and had not discharged the odor were respectively introduced into petri dishes that had previously confined one Lacodid spider, Pardosa astrigera. The death rate of the scent-discharging crickets after 24-hr was 65% (N=20), while in the other group the death rate was 26.3% (N=19). A significant difference between them was found at the 5% level. Also in another experiments, it was found that filter paper soaked up the odoriferous secretion from cricket repelled ants, Tetramorium caespitum. These findings indicate that the scent emitted by the crickets acts as their defense against predators.

The source of the scent in the cricket was a pair of exocrine glands located in the 2nd-segment whose opening was situated on the lateral wall of the 2nd-sternum.

This is the first report of a chemical defense utilized by Tridactylid insects.

#30

"THE OBSERVER", AN INTEGRATED SYSTEM FOR EVENT RECORDING AND DATA ANALYSIS IN BEHAVIOURAL RESEARCH. L.P.J.J. Noldus, Department of Entomology, Agricultural University, Wageningen, The Netherlands.

Event recorders form an important tool in any kind of behavioural research that involves direct observation of animals. Cheap portable microcomputers are available that can be programmed for this purpose. However, one needs programming experience to write an efficient event recording program, and each new experimental design may require a different one. Further, small portable computers mostly have limited data storage capacity so that data analysis can best be done on a PC.

THE OBSERVER is a menu-driven, interactive program written for an IBM-PC in conjunction with a TRS-80 Model 100 microcomputer. Configuration of the event recorder and analysis of data files take place on the PC, while the actual event recorder program runs on the Model 100. THE OBSERVER includes the following modules: I. Configuration of an event recorder program. The user can define up to 58 keys as events, in up to 4 classes of mutually exclusive events. Various labels can be defined. One can enter up to 20 questions to be 'asked' by the event recorder and of which the answers are stored together with the data. On the basis of this information, THE OBSERVER subsequently writes the event recorder program. II. Data transfer from PC to Model 100. III. Data transfer from Model 100 to PC. IV. Data analysis. For each observation, frequency and duration of all possible combinations of events are calculated. Output options include a text file containing a detailed report for each observation, and a table in a format suitable for direct import into Lotus 1-2-3, that can serve as an interface with other statistical programs. V. A help facility that can be invoked at various places in the program.

#31

REMOVAL AND SUBSEQUENT INGESTION OF RIVALS' SEMEN DURING COPULATION IN A TREE CRICKET.

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Many male adaptations which help to increase paternity result from sperm competition, a form of sexual selection that acts during, as well as after, copulation. A novel combination of such adaptations in the tree cricket *Truljalia hibinonis* (Matsumura) (Podoscirtinae: Gryllidae) is described. It is shown that the semen (spermatozoa and seminal fluid) transferred by the last male to copulate accounts for 87.5% of all semen in the female's sperm storage organ. The semen of previous males is displaced onto the penis of the copulating male and is removed from their genitalia and ingested it, thereby possibly recouping some of their mating effort. No overt morphological adaptations for sperm removal were observed and, on the basis of anatomical evidence, it is suggested that rivals' semen is flushed out of the female's sperm storage organ by the semen of the last male.

#32

DEPTH VISION IN THE HAWK MOTH *MACROGLOSSUM* - BEHAVIOURAL EVIDENCE FOR POSSIBLE MECHANISMS.

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The foraging hawk moth *Macroglossum* terminates its approach by two to four discrete decelerating phases in well defined distances to the flower. These distances are independent of the speed of approach and the size of the flower. Apparently the animal perceives distance without using these parameters. When a flower is moved towards and away from the tethered flying moth, the animal reacts by lifting and lowering its abdomen, also in discrete steps. These findings indicate depth perception by means of binocular stereopsis. But this needs not to be the only mechanism the animal uses. Pilot experiments, in which the moth had to find blue flowers in front of a blue-and-white random dot pattern, revealed a clear correlation between the distance flower-background and the frequency of visits. So motion parallax information is used by the moth to find flowers in a highly structured surround and could also be used to obtain additional depth information.

#33

DEMONSTRATION OF MALE SCENT- AND FEMALE PHEROMONE- GLANDS IN *SPILOSOMA OBLIQUA* WALKER (LEPIDOPTERA: ARCTIIDAE). Y.H. Prasad and K.R. Kanauja*, Department of Entomology, G.B. Pant University of Agriculture & Technology, Pantnagar, 263 145, India.

Many Arctiids are known to possess male scent organs and utilize the aphrodisiac for mating. We report here the presence of a well developed scent organ in the males and pheromone gland in the females of a polyphagous hairy caterpillar, *Spilosoma obliqua* Walker. Male moths possessed a paired, globular, fused at the base and arisen through an invagination of intersegmental membrane of the abdominal sternites. The gland was thickly covered by long irregular hairs at the apical regions possibly to facilitate evaporation of the aphrodisiac. Female pheromone glands were elongated, 3 sac like structures fused together and located between sternites 8 and 9. Male and female moths extruded the glands through a typical posture. Detailed observations on mating behaviour of moths are reported and precise role of pheromone in mating is discussed.

#34

TANNIC ACID, PROTEINS AND DIGESTIBLE CARBOHYDRATES: AN INVESTIGATION OF INTERACTIVE EFFECTS IN INFLUENCING FEEDING BY *LOCUSTA MIGRATORIA* AND *SCHISTOCERCA GREGARIA*. David Raubenheimer, Department of Zoology, Oxford University, South Parks Road, Oxford, OX1 3PS, United Kingdom.

Numerous studies investigating a defensive role for plant tannins against insect herbivores have produced different, often conflicting results. Recent work on locusts has investigated the behavioural and physiological mechanisms of compensation for dietary nutrients. What has not been studied are possible interactive effects, in which insects respond differently when tannins are present in food containing different levels of nutrients. I have therefore investigated the effect varying levels of both protein and digestible carbohydrate (28 or 14% dry weight) in artificial diets containing either no tannic acid or 10% by dry weight. Effects on total consumption and detailed feeding behaviour are reported for the oligophagous *L. migratoria* and the polyphagous *S. gregaria*.

#35

GYPSY MOTH (*LYMANTRIA DISPAR* (L.)), LEPIDOPTERA: LYMANTRIIDAE) LARVAL PREDATION IN THE LABORATORY BY *PTEROSTICHUS PENNSYLVANICUS* (LEC.) (COLEOPTERA: CARABIDAE). R. Marcel Reeves, Department of Entomology, University of New Hampshire, Durham, New Hampshire, U.S.A. 03824.

Adult *P. pensylvanicus* were fed larval stages 1-5 of gypsy moth. Feeding rates were higher for female predators than for males in all prey stages. Feeding rates for both sexes were highest for L₁ larvae and became progressively lower in each subsequent stage. Initial attack most frequently occurred at abdominal segments 1-4. If feeding was completed, all that usually remained were one or more tubercles with attached setae.

#36

RECOGNITION AND EVALUATION OF LEAF SIZE BY THREE ATTELABID WEEVILS (COLEOPTERA). Kazuhiko Sakurai, Dept. Zool., Fac. Sci., Kyoto Univ., Sakyo, Kyoto, 606 Japan.

Female attelabid weevils have a characteristic habit of parental care. Many of them make a variety of leaf-roll cradles, in which single or multiple eggs are laid. In order to reveal a part of Umwelt of three attelabid weevils (i.e. *Chonostropheus chujoi* Voss, *Deporaus* sp. and *Apoderus balteatus* Roelofs), several series of model leaf experiments were carried out.

In the three species, female weevils perform stereotypic behaviour before cutting, and the walking course of a species in that stage corresponds with the determinant of cutting point of the species. These evidence and the results of a sliding leaf model of *Deporaus* sp. show that weevils perceive and evaluate leaf size by the walking. This study also demonstrates that these weevils have a common cognitive structure: they perceive at least two different categories of size, i.e. one as the determinant of the cutting site and the other as the determinant of egg number.

#37

BIOLOGICAL ASPECTS OF AN OVIPOSITION-DETERRING PHEROMONE (ODP) IN TWO *PIERIS* SPP. L.M. Schoonhoven, Department of Entomology, Agricultural University, Wageningen, the Netherlands.

Ovipositing Large White Butterflies (*Pieris brassicae*) avoid laying eggs in close proximity of conspecific eggs. The presence of eggs is among other factors recognized by the presence of an oviposition deterrent pheromone (ODP) (Rothschild & Schoonhoven, 1977). Small White Butterflies (*P. rapae*) are deterred from egg-laying by the presence of *P. brassicae* ODP (Klijnsma, 1985).

The present study was done to investigate (1) whether *P. rapae* produces its own ODP, (2) whether *P. brassicae* responds to *P. rapae* ODP, and (3) to locate the origin of the pheromone. Behavioural methods employed methanol washings of eggs and water extracts of female accessory glands. Electrophysiological techniques were used to study responses of tarsal contact chemoreceptors after stimulation with ODP extracts (Behan & Schoonhoven, 1978).

Results showed that *P. rapae* produces an ODP, which is present on its eggs and in its accessory glands. *P. brassicae* responds to *P. rapae* ODP and vice versa. The ODP stimulates in both species a deterrent receptor in tarsal chemoreceptive hairs.

#38

ORIENTATION RESPONSES OF *Manduca sexta* LARVAE TO TEMPORALLY PRESENTED CUES DERIVED FROM HOST PLANT

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A computer program defined a simulated 'patch' of host plant volatile within a 'habitat' of clean air; successive encounters of the *Manduca sexta* larvae with the non-cue (or unfavorable condition) were recorded to delineate the overall strategy of finding and remaining within a resource of this kind. Because the status of the air was made to change relative to the movements of the larvae, and because the air containing host plant volatiles or clean air moved vertically and not in the plane of larval orientation, it was only possible for the larvae to return to the zone of plant volatiles based entirely on its responses to temporal changes in airborne cues (host plant vs clean air). The results indicate that *Manduca sexta* larvae recognize the 'edge' of the experimental resource patch through temporal comparisons of external chemosensory information, and suggest that the larvae return to the resource patch using genetically stored and possibly idiothetic information.

#39

SEX PHEROMONE COMPONENTS OF THREE "SPECIES" WITHIN THE DINGY CUTWORM COMPLEX, *FELTIA JACULIFERA* (GN.) (LEPIDOPTERA: NOCTUIDAE). D.L. Struble*, J.R. Byers, A. Tron and C.E. Herle, Agriculture Canada Research Station, Lethbridge, Alberta, Canada T1J 4B1.

The sex pheromone components of two "species" of dingy cutworm from southern Alberta and one from near Ottawa, Ontario, were identified in extracts of abdomen tips from calling female moths. The "species" are morphologically indistinguishable and their flight periods overlap, but their male antennal responses and female sex pheromones are discrete. The chemical identifications were done by gas chromatography-mass spectrometry and by gas chromatography with flame ionization and electroantennographic detectors simultaneously. Detector antennae were from several species of moths. The main pheromone components for the three "species" involved different ratios of (Z)-7-dodecenyl acetate, (Z)-9-tetradecenyl acetate, and (Z)-11-hexadecenyl acetate. In field tests for the two western "species", synthetic blends were "species" specific and competitive with live females.

#40

ELECTROANTENNOGRAPHIC RESPONSES DIFFERENTIATE "SPECIES" WITHIN THE DINGY CUTWORM COMPLEX, *FELTIA JACULIFERA* (GN.) (LEPIDOPTERA: NOCTUIDAE). J.R. Byers*, D.L. Struble, J.D. Lafontaine and C.E. Herle, Agriculture Canada Research Station, Lethbridge, Alberta, Canada T1J 4B1. (Biosystematics Research Centre, Ottawa, Canada K1A 0C6)

The dingy cutworm is one of the more common and widely distributed of North American noctuids. Recently, identification of sex pheromones from isofemale lines has demonstrated the existence of discrete "pheromone species". Screening of the antennal responses of field collected male moths to a standard test blend of pheromone components has revealed the existence of two "pheromone species" of the dingy cutworm on the prairies of western Canada and at least two others in eastern Canada. The "species" are morphologically indistinguishable and so far as known have similar life histories and biology. The two prairie "species" are known to be broadly sympatric with seasonal flight periods that overlap to a considerable extent. Although hybrids can be obtained in the laboratory there is no evidence of hybridization in the field. In the prairie "species" with the widest range of response profiles there is evidence of assortative attraction within populations and differentiation between populations. The pheromone system of the dingy cutworm is apparently rather plastic resulting in a mosaic of "species" that have not differentiated morphologically.

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THE ROLE OF LEAF CUTICLE IN HOST SELECTION BY THE WHITEFLY *PARABEMISIA MYRICAE* (HOMOPTERA: ALEYRODIDAE) ON CITRUS. G.P. Walker*, Department of Entomology, University of California, Riverside, California, USA 92521

The behavior of *P. myricae* adults on young (preferred) and mature (non-preferred) lemon leaves (*Citrus limon*) was studied in detail. *P. myricae* was more likely to initiate probes on young than on mature leaves and the duration of probes was longer on young ($\bar{x}=10$ sec) than on mature leaves ($\bar{x}=306$ sec). Eighty-three percent of the probes on mature leaves were terminated within 15 sec of initiation, suggesting that *P. myricae* was repelled by properties of the cuticle and/or outer epidermis. To evaluate the role of leaf cuticle in probing behavior, cuticles (enzymatically removed from young and mature lemon leaves) were used as membranes covering a probing substrate (sucrose solution). For whiteflies to feed on the probing substrate, they had to penetrate the cuticles in the same manner as they have to penetrate a cuticle to reach the interior of a leaf. Differences in probe duration on young and mature cuticles were similar to previously observed differences between young and mature leaves, suggesting a major role for the cuticle in leaf age preference by *P. myricae*. Comparison of results from experiments using young and mature cuticles and Parafilm (a "neutral" membrane) over sucrose solutions, suggested that mature cuticles were inhibitory rather than simply non-stimulatory.

EVOLUTIONARY PATTERNS IN THE CHEMISTRY AND FUNCTION OF DUFOUR'S GLAND IN BEES. A. Hefetz, Department of Zoology, Tel Aviv University, Ramat Aviv 69978, Israel.

The Dufour's gland in bees is a rich source of diverse natural products. In the ground-dwelling bees the secretion is mostly used for lining the brood cells with a hydrophobic lining. Whereas in several species the lining constitutes an unmodified secretion, in others it is formed only after chemical transformation. The diversity of the chemical means by which hydrophobicity of the brood cells is achieved suggests that it is polyphyletic.

Several species also use Dufour's gland secretion to mark their nest entrance. In these species, each individual bee possesses its own chemical composition by which it can discriminate between self and strange secretions. That this is genetically determined can be inferred from the finding that in the social halictid *Evyllaes malachurum* the blends of nestmates (considered as sisters) are more similar to each other than non-related conspecific bees. It is possible that this congruency in the secretions forms the basis for kin recognition.

Dufour's gland exudates possibly evolved for coating structures in solitary species, and then adapted for self communication in aggregative bees and for intraspecific communication in the eusocial species.

REACTION OF HONEYBEE WORKERS TO VOLATILE COMPONENTS OF QUEEN SIGNALS. R.M. Crewe* and R.F.A. Moritz, Dept. of Zoology, University of the Witwatersrand, P.O. Wits, 2050 South Africa.

Honeybee workers (*Apis mellifera*) were tested in a metabolic bioassay for their response to odors of semiochemicals identified in the mandibular glands of queens and of chemically related compounds. (E)-9-oxodec-2-enoic acid (9-ODA), the queen substance proved to be the most active single component of the queen's MG secretion. Three other compounds tested did not release stronger reactions than related compounds not present in the secretion. Workers react to 9-ODA as an olfactory signal and not by contact perception. The volatile signals from live queens released stronger reactions from the workers than the MG extracts. Semiochemicals other than the MG secretions seem to be responsible for this phenomenon.

STRUCTURAL ECLECTICISM OF BEE SEMIOCHEMICALS

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The complex secretions of bees comprise multicomponent multifunctional mixtures among which methylketones and respective carbinols, hydrocarbons and esters represent the majority both with regards to variety and amounts. While some of the compounds are typical terpenes or polyketids, most structures show acetate subunits; branchings due to propionate units are seldomly found. Specificity in closely related species is often based on variation of relative proportions in qualitatively similar bouquets.

Most of the unbranched hydrocarbons, ketones and alcohols show uneven numbers of carbon atoms. Alkenes usually show a Z-double bond in position 9 starting from one end, while in unsaturated ketones and methylcarbinols double bonds are often found at even positions. The presence of chiral methylcarbinols opens a chance for variation of enantiomeric compositions. Esters of the wax type form by far the most versatile group of compounds: Variation of chain lengths on either side of the functional group, the use of unsaturated acids and/or alcohols as well as chiral methylcarbinols opens an unlimited source of diversity.

Many species show sex-specific and age-dependent features.

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INTRA- AND INTERSPECIFIC FUNCTION OF EXOCRINE SECRETIONS IN THE AFRICAN TERMITE *SCHEDORHINOTERMES* (ISOPTERA)

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Chemical signals from various exocrine glands have been shown to regulate communal activities in termite colonies. In *S. lamanianus* the odour blends released from both, the sternal gland secretion (SGS) of all castes and the frontal gland secretion (FGS) of the soldiers coordinate in peripheral districts of the termite colonies' territory gallery-building, foraging, recruitment, alarm, and defense.

The sternal gland is well developed in workers and in minor soldiers. Gallery building is (dose dependant) directed along pheromone trails (SGS). Foraging follows initial trails by minor soldiers leading workers to food sources. Recruitment trails by worker SGS initiate mass-recruitment. Because of their higher sensitivity to SGS of either caste, minor soldiers operate more distant from pheromone trails than workers, thus protecting the unarmed workers.

The FGS of minor and major soldiers is composed by aliphatic ketones. Interspecifically - as one of the termites' defense strategies - FGS of both soldiers inhibits ant recruitment to the termite colony, thus minimizing predation. Intraspecifically, however, minor soldiers FGS only elicits alarm in both workers and soldiers. In addition FGS inhibits following SGS trails near threshold concentration being typical for foraging in unprotected areas.

CHEMICAL VARIATIONS OF THE DEFENSIVE SECRETIONS IN NEW GUINEAN *NASUTITERMES*: SIGNIFICATION AND IMPORTANCE. C. Everaerts*, Y. Roisin and J.M. Pasteels, Laboratoire de Zoologie, UA CNRS 674, Université de Bourgogne, 21000 Dijon, France.

The frontal secretions of several New Guinean *Nasutitermes* soldiers were scrutinized. These defensive secretions are mainly constituted of mono- and diterpenes.

We observed large interspecific variations, but according to the species and to the chemicals studied, we also found some significant intraspecific differences.

The variations are discussed at inter- and intraspecific levels in point of view of ecological and biological importance.

BEE SOCIOCHEMICALS. R.M. Duffield (USA)

No Abstract

ECLECTIC CHEMISOCIALITY OF THE HYMENOPTERA. Murray S. Blum*, Laboratory of Chemical Ecology, Department of Entomology, University of Georgia, Athens, Georgia 30602, USA.

Great natural product eclecticism characterizes the chemical signals utilized by eusocial Hymenoptera. Phenological correlates with the production of pheromones demonstrate that individuals are programmed to biosynthesize particular compounds with great temporal precision. Queens and workers generate caste-specific pheromones that have been evolved to regulate a multitude of key social interactions. The chemical bases of pheromones utilized for releasing alarm behavior, trail following, and sexual attraction will be analyzed in order to focus on the great structural diversity that characterizes these messages in ants, bees, and wasps. The evolution of novel anti-aggression pheromones will be discussed in order to emphasize the versatility and adaptiveness of chemisociality in the colonial milieu. The significance of pheromonal blends will be explored as a means of stressing the importance of idiosyncratic compounds as key information-transfer agents. An examination of the qualitative multifariousness of these chemical signals will explore the significance of what would appear to be a great "plethora of information" in the message.

PHEROMONES OF BUMBLEBEE AND ANT SPECIES. G. Bergstrom (Sweden)

No Abstract

BEHAVIORAL AND CHEMICAL HIERARCHY IN THE RECRUITMENT OF FIRE ANTS: SPECIES-SPECIFICITY AND POPULATION DYNAMICS. R. K. Vander Meer, USDA/ARS, P.O. Box 14565, Gainesville, FL 32604.

The recruitment pheromone of *Solenopsis* Spp. is produced by the Dufour's gland and exits via the sting apparatus. The contents of this gland elicit a variety of behaviors in worker fire ants, such as alarm and colony migration, as well as recruitment. Our investigations into the behavior and chemistry of the recruitment process have led to the discovery of a hierarchy of requisite behaviors that, in the case of *Solenopsis invicta*, are controlled by specific blends of components produced in the Dufour's gland. This was used to demonstrate species-specificity of recruitment for *S. invicta* and *S. richteri*, two South American species forced into sympatry through their accidental importation into the U.S. Further, the recruitment hierarchy provided behavioral evidence for hybridization between these two species. A hypothesis for the current distribution of *S. invicta*, *S. richteri*, and their hybrid will be presented based primarily on competition in the foraging arena and differential responses to each others recruitment pheromones.

SOCIAL EXOCRINOLOGY: VENOMS AND THE EVOLUTION OF SOCIALITY. J.O. Schmidt, Southwestern Biological Institute, W. Brichta Dr., Tucson, AZ 85745, U.S.A.

Hymenoptera are unique among the insects in the possession of a sting and in evolving sociality multiple times. Are these characters independent or related? I provide evidence that the two are related and that the aculeate sting apparatus and venom, an exocrine product of the sting apparatus, were major preadaptations that allowed sociality to evolve.

ADVANCES IN OUR UNDERSTANDING OF THE ENERGETICS OF SOCIALITY. M. G. Nielsen, Institute of Zoology and Zoophysiology, University of Aarhus, DK-8000 Aarhus C, Denmark.

Interest in energetics of social insects was stimulated by the IBP in the late 60's and early 70's and culminated in the publication of "Production Ecology of Ants and Termites". This volume was the first attempt to collect the scattered data and use it in the description of the impact of social insects on ecosystems.

In the ten years since its publication interest in the topic has been maintained and this Symposium will provide a timely opportunity to review the present status of our knowledge of the energetics of sociality, but on this occasion encompassing all the groups of social insects. However, the constraints of the programme require us to consider just four aspects of energetics but we hope that they will be broad enough to provide a sound overview. The dominance of social insects in such a wide range of ecosystems stems from their ability to exploit the environment through the efficiency of the foraging methods and their ability to gather the resources necessary for social homeostasis and the successful production of reproductive propagules. The four topics chosen emphasise those features of the social insects which distinguish them so clearly from all other insects.

THE COSTS AND REWARDS OF FORAGING AMONG SEED HARVESTING ANTS (MESSOR). C. Baroni Urbani* and M.G. Nielsen, Zoology Institute, University of Basel, Basel, Switzerland, and Institute of Zoology and Zoophysiology, University of Aarhus, Aarhus C, Denmark.

In *Messor capitatus* oxygen consumption during running is proportionally higher for very small ants (4-10 mg FW) but relatively constant for medium size or large ants (10-21 mg FW). Large ants, however, represent just a small proportion within a natural population and take little part to food transport. Due to a marked preference for items 20-30 times heavier than an ant body, foraging represents a high energy consuming activity which is rewarding only under some behavioral constraints which have been observed in *M. capitatus*: (1) precise rectilinear trails to the food source (2) relatively low population investment in foraging but uninterrupted over the 24 hours period and (3) optimal reduction of individuals devoted to other tasks like defence, alarm, and territorial patrolling.

ENERGETIC COSTS OF FORAGING: A COMPARISON OF LEAF-CUTTING ANTS AND ARMY ANTS (HYMENOPTERA: FORMICIDAE). D.H. Feener Jr.*, J.R.B. Lighton and G.A. Bartholomew, Laboratory of Biomedical and Environmental Sciences, University of California, Los Angeles, California, USA 90024.

Leaf-cutting ants in the genus *Atta* and army ants in the genus *Eciton* are among the most conspicuous and spectacular ants in the American tropics. Although these ants differ widely in their social organization and foraging ecology, foragers of both *Atta* and *Eciton* often travel over 100 m to food sources. Such long distances to food sources suggest that energy costs associated with food collection should be a substantial part of a colony's energy budget. We measured standard rates of O_2 consumption (VO_2) and net and gross costs of transport (NCOT and GCOT) in *Atta colombica* and *Eciton hamatum*. NCOT and GCOT decreased with increasing body size in both species with values substantially lower in *E. hamatum*. Despite the heavier loads carried by *A. colombica*, load carriage increased NCOT proportionally to the increase of body mass + load mass in both species. Based on our measurements we develop a model to predict the energy costs of foraging and maintenance of *Atta* and *Eciton* colonies and relate differences in these costs to differences in morphology, behavior and ecology.

ENERGY CONSUMPTION BY THE SEXUALS OF *LASIUS FLAVUS* DURING MATURATION. G.J. Peakin* and M.G. Nielsen, Department of Life Sciences, Goldsmiths' College, Lewisham Way, London SE14 6NW, England.

After emergence from the pupa, the sexuals of ants generally spend a period maturing before the mating flight. This period is marked by substantial physiological changes which have important implications for the colony. The gynes, in particular, build up a considerable reserve of nutrients to see them through colony foundation.

In a period as short as 6 days, the gynes of *Lasius flavus* increased their dry weight 3.4 times, 60% of which was fat. It is clearly in their interests to conserve this energy, since they will not be able to replenish it until they have reared the first batch of foragers. To this end the respiratory rate, after rising to a peak during the period of the accumulation of reserves, declined to a very low level which was sustained during the wait in the nest until the mating flight and through the initial period of colony foundation. As a consequence the energy losses due to respiration represented no more than 6% of the total energy accumulated during the maturation period.

ANT SEX RATIOS IN TERMS OF ENERGY. J.J. Boomsma, Department of Population Biology and Evolution, University of Utrecht, Padualaan 8, 3584 CH Utrecht, The Netherlands.

The sex ratio of ants is one of the most prominent test cases in current evolutionary biology. Inclusive fitness theory makes detailed predictions as to how sex ratio strategies in haplodiploid social insects should have been moulded by natural selection. Theoretically, the sex ratio optima are all formulated in terms of investment, i.e. the cumulative amount of energy allocated to females and males, respectively, between the egg stage and their nuptial flight. This imposes severe constraints on the evaluation of empirical sex ratio data, as precise estimations of the energetic cost involved in the production of an offspring of either sex are hard to obtain. From a case study on the ant *Lasius niger* and a review of literature data on ant sex ratios, it will be argued that approximations of investment based on sexual (weight) dimorphism are of limited value as they are both rather inaccurate and have a high probability of being systematically biased. It follows that trends in weight sex ratios across ant species are likely to be similarly biased and that such data are thus largely unsuitable for testing inclusive fitness theory. Possibilities to avoid these problems will be discussed and a potentially unbiased design for testing sex allocation theory in field populations of ants will be presented.

NEST BUILDING: THE COSTS OF PERSONAL SECURITY AND ITS SOCIAL CONSEQUENCES. Michael Hansell, Department of Zoology, University of Glasgow, Glasgow G12 8QQ, Scotland, U.K.

Social insects use a variety of materials to construct their nests. The majority use more than one material and these often include both material collected from the environment and products of the animals' own metabolism; for example, the nest paper of social wasps. Only in rare cases is even the majority of the nest made of a single material. The difficulties this presents for the measurement of energetic costs and the present state of our ignorance will be outlined.

With their nests, insects have bought security against an uncertain future. Termite mounds, which buffer the occupants against fluctuations in the physical and biological world outside and which last for decades, represent the most extreme development of this.

The amount of security purchased by nest building, its durability and its costs now seem likely to have had significant effects on the evolution of insect social behaviour. It also seems probable that building costs may have been substantially changed in evolutionary history through changes in the organisation of the workforce, changes in nest architecture and changes in materials technology. Possible examples of these will be identified and the need for studies on costs to resolve evolutionary issues will be discussed.

ENERGETIC INVESTMENT IN THERMO-CONTROL BY SOCIAL HONEY BEES OF NORTH TEMPERATE CLIMATES. E. E. Southwick, Department of Biology, State University of New York, Brockport, NY 14420 USA

Group size is probably the most important factor in precise thermo-control and overwintering success in the highly eusocial colonies of honey bees (*Apis mellifera carnica* Poll.) under cold-temperature stress. Those races of *Apis* living in northern climates show several cooperative social behaviors that enhance the group's chance of survival. Clustering at cool temperature greatly reduces heat loss. Individuals within the group coordinate their rates of heat production temporally and respond together to environmental temperature stress. At moderate environmental temperatures (5-15°C) groups show circadian patterns of metabolic heat production linked to photoperiod. At warmer temperatures the rhythm disappears and coordinated fanning ventilates and cools the nest. At cooler temperatures the heat production rises to meet the demands of heat loss. *A. m. carnica* regulates the brood temperature around 35°C and the cluster surface temperature above 9°C with an optimum (least costly) environmental temperature of about 6°C (range -10° to +10°C). Tropical social honey bees such as the hybrid resembling the African honey bee, *A. m. scutellata* Lat., in South and Central America, exhibit some similar social responses to cold stress even though they exist in climatic regions in which they never would experience such thermal demands.

CHANGES IN RESPIRATORY RATE AND ENERGY CONTENT DURING PUPAL DEVELOPMENT IN THE GYNES OF *LASIUS FLAVUS*.

M. G. Nielsen* and G. J. Peakin, Institute of Zoology and Zoophysiology, University of Aarhus, DK-8000 Aarhus C, Denmark.

For many ant species the production of sexuals represents a substantial drain of energy from the society. A not inconsiderable proportion of the energy is devoted to metamorphosis from the larva to adult.

The respiratory rate and changes in body composition have been investigated in gynes reared in the laboratory and collected from the field as a function of pupal development. The time from the initiation of cocoon spinning until the emergence of the adults took 33 days at 20°C. Respiration conformed to the U-shaped curve characteristic of insects. At the start of metamorphosis, at its lowest point and just before eclosion of the adults it was 1.79, 0.95, and 2.56 $\mu\text{l}/\text{mg}$ dry weight/h at 30°C, respectively. During this period the gyne pupae lost 36% of their dry weight and 30% of this was fat.

These results will be discussed in relation to the energy investment in the economy of the ant society.

ENERGY INVESTMENT IN GYNES OF ANT SOCIETIES. L. Keller*1 and L. Passera2. 1) Museum of zoology, Palais de Rumine, C.P. 448, 1000 Lausanne 17, Switzerland. 2) Laboratoire d'entomologie, U.P.S., 118, rte de Narbonne, 38000 Toulouse France.

In social insects, the number of gynes produced and their probability of succeeding in colony founding depend on the mode of colony founding adopted by species. In ants, there are two main modes of colony founding, namely the independent and the dependent modes. In the first case, gynes start colony founding without the help of workers, whereas, in the second case, queens are helped by workers. To compare the adaptive value of these two strategies, we studied the physiological status of gynes of ca. 30 ant species. Between the time of emergence and mating, gynes of species having an independent mode of colony founding accumulate a high amount of fat reserves (ca. 60 % of their dry weight) that will be used to rear their first brood. In contrast, gynes of species with a dependent mode of colony founding as well as parasitic species accumulate only a little amount of fat reserves (20-35 % of their dry weight). Their production necessitates therefore a lower amount of energy investment for the society. These results are discussed with regard to the evolution of social behavior in ants.

SOME THOUGHTS ON FUTURE RESEARCH ON THE ENERGETICS OF SOCIALITY. G.J. Peakin, Department of Life Sciences, Goldsmiths' College, Lewisham Way, London SE14 6NW, England.

Within the four topics addressed during the Symposium it will be possible to identify gaps in our knowledge which should suggest ways forward in the next few years. In addition the constraints imposed by the programme will highlight other areas of research that will be required in order to add to our understanding of the energetics of sociality and give us a clearer idea of the impact of social insects in the ecosystem.

A major advance has been the construction of models to describe the attributes of sociality. The application of these models to a greater variety of field situations and for a more extended period will certainly be an important preoccupation for our research. A fuller understanding of the energetics of sociality will also require a more widespread application of physiological studies.

It is hoped that the Symposium will provide a useful stimulus for closer collaboration between the teams working on each of the social insect groups and that the vitality of the IUSSI will ensure an appropriate forum for the continued interchange of ideas.

CHEMICAL SIGNALS AND DOMINANCE COMMUNICATION IN BEES
Hayo H.W. Velthuis, Laboratory of Comparative Physiology,
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In this contribution I will address the following issues: the kind of signals involved in dominance communication; the evolutionary origin of chemical signals now used in a social context; the chemical complexity of a dominance pheromone; the melting together of individual odours into a colony odour; the learning and recognition of individual blends; biophysical modulations masking individuality; the chances for kin recognition in a complex society.

PHEROMONES AND CASTE SPECIFIC FUNCTIONS IN STINGLESS BEE REPRODUCTION. W. Engels, W. Francke and E. Engels, Zoological Institute, University of Tübingen, and Institute of Organic Chemistry and Biochemistry, University of Hamburg, Germany.

The highly eusocial organisation of stingless bee colonies apparently depends in a remarkable extent on elaborate systems of chemical communication. Alarm pheromones and scent marking of trails to food resources have been studied in a number of species already, but nothing was known on chemocommunication involved in reproduction. We analysed the age-dependent attractiveness of a queen for the drones and corresponding patterns of volatiles, the role of male aggregations in mating biology, and ontogenetic changes in cephalic worker odorous secretions. Bioassays were developed to test drone and worker reactions to identified compounds. In stingless bees caste specific differences and pheromonal functions in relation to reproduction seem to be even more pronounced than in honey bees. In addition stingless bees evidently have evolved much more interspecific variation in semiochemicals. This can be interpreted as a demarcation strategy of species specificity in tropical environments with a carrying capacity of highly diverse social bee communities. This can be demonstrated at least for the neotropics.

(Supported by DFG research grants).

INDIVIDUAL BADGES AND SPECIFIC MESSAGES IN MULTICOMPONENT PHEROMONES: CASE STUDY OF DUFOUR'S GLAND IN BEES. A. Hefetz, Department of Zoology, Tel Aviv University, Ramat Aviv 69978, Israel.

The information encoded within many pheromones encompasses several levels of recognition. In sympatric species, species specificity overlays the trivial information transmitted by the pheromone. Aggregating bees that mark their nest entrances with Dufour's gland secretion use individual blends, while in species that live in mixed aggregation the chemiosignal must be both species specific and individual. The question arises how many of the compounds, present in a certain blend, are needed to specify each level of recognition.

Chemical analyses of Dufour's gland secretions of twelve species of halictine bees, representing all levels of sociality, formed the basis for constructing a computer algorithm aimed at answering this question.

The number of components needed to achieve specificity increases with the number of bees involved, or as the level of specificity increases. Of the 27 compounds that may be present in a certain species only about 2-5 are needed to signify a genus or a species, a blend of 6 to impart individual badges to 12 unrelated conspecifics, or 15 compounds if the bees are nestmates. Within these constraints a species may use individual, gestalt or queen dominated secretions to compose kin specific odours.

CHEMICAL COMMUNICATION AND SOCIAL EVOLUTION IN ARMY ANTS AND SOCIALLY PARASITIC ANTS. N.R. Franks* and A.F.G. Bourke, School of Biological Sciences, University of Bath, Bath BA2 7AY, U.K.

Army ant workers are involved in a unique form of social and sexual selection in which they choose, on the basis of chemical communication, both the mothers and fathers of new colonies. After discussing this we will point out some of the many fascinating parallels that exist between this selection in army ants and the acceptance of foreign parasitic females into colonies of their hosts. Such parallels emphasize that, as with other forms of communication, insect chemical communication may be used as a means of manipulation and deceit. We will then pursue the theme of chemical communication by considering other relevant aspects of the lives of social parasites, particularly sexual selection.

EXOCRINE AND ENDOCRINE SIGNALS IN TERMITE CASTE DIFFERENTIATION. G.D. Prestwich* and M.A. Mohamed, Department of Chemistry, State University of New York, Stony Brook, New York 11974-3400, USA.

A molecular understanding of the control of caste differentiation remains one of the unsolved problems in developmental biology of social insects. Recently, we have shown changes in the hemolymph JH-binding proteins of the termite *Reticulitermes flavipes* which occur during natural or chemically-induced differentiation of workers to soldiers. These subtle biochemical changes are detected by photoaffinity labeling of the JHBPs with ³H-EFDA followed by SDS-PAGE and fluorography. This assay has allowed study of (i) comparison of effects of IGRs *in vivo* and *in vitro*, (ii) determination of time course of JHBP changes in natural or methoprene-treated termites, and (iii) comparison of JHBPs of natural castes. Most exciting is the use of this assay to demonstrate the existence of soldier- and nymph-produced primer pheromones which act to suppress methoprene-induced differentiation. Results on partial purification of these prototypical primer pheromones will be discussed.

PHEROMONE SIGNALLING DURING CONTEST SETTLEMENT AND MATE CHOICE IN BEES (fam. HALICTIDAE). B.H. Smith, ARL Division of Neurobiology, University of Arizona, Tucson, AZ 85721

The macrocyclic lactone pheromone emanating from the Dufour's gland of female halictine bees is involved in both mate choice by males and in intraspecific agonistic interactions among gynes. Males discriminate among females based on learned associations during mating attempts. Thereafter, males attempt to avoid females with whom they have attempted to mate in the past, and also generalize this avoidance behavior to the female's kin. The evolutionary consequences of this generalization are different from simple avoidance of familiar females. Gynes of the social species go through an obligate solitary phase during which time they may, depending on the species, fight over possession of nests containing developing worker brood. These interactions may influence evolution of caste dimorphisms. Larger gynes, who possess more of the pheromone, have an advantage in these encounters, although other factors, e.g., nest ownership, play a role as well. Application to the smaller of two interactants of small amounts of a synthetic lactone pheromone mixture alters the behavioral strategy employed by the larger. A model incorporating these considerations predicts the conditions under which this type of intraspecific parasitism emerges, as well as certain other behavioral strategies of nesting gynes.

EVIDENCE FOR REPRODUCTIVE COMPETITION AMONG MALE STINGLESS BEES (HYMENOPTERA: APIDAE). D. W. Roubik, Smithsonian Tropical Research Institute, Apartado 2072 Balboa, Republic of Panama

Studies on male stingless bees treat <10% of major supraspecific groups but suggest diverse behavior and ecology. Males of several matrilineal occur in nests of stingless bees and potentially compete for food and mates. Males are produced by the queen and/or workers. Competition begins among larvae, only one of which will emerge from multiple worker-laid eggs placed with the queen's egg in a single brood cell. Adult males receive proteinaceous food only from older workers, thus potentially from their own mother. Males form aggregations that await virgin queens 1) near the parent nest; 2) near an established conspecific nest, or 3) at a new nest of an incipient colony. Males probably find incipient nests by following workers. Male aggregations contain a few to several thousand bees from multiple colonies. *Scaptotrigona pectoralis* was found to form potential male leks of several thousand at 5 m from nests. A few dozen to a few hundred males might be found in their natal nest but are said to leave after a few weeks. I found a nest of *Scaptotrigona barrocoloradensis* containing 3470 workers but 1731 males—likely including those of other colonies. Since meliponine males sometimes help in nest construction, ripen honey, forage nectar at flowers and produce wax, they have traits that could allow them to enter host nests. Adult male stingless bees display no apparent aggressive devices or traits. This does, however, overlook possible repellent odors or other chemicals about which there is little information.

EXPERIMENTAL DEMONSTRATIONS OF THE NATURE OF SEXUAL SELECTION INVOLVING PHEROMONES IN A COCKROACH, *NAUPHOETA CINEREA* (OLIVIER). A.J. Moore, EPO Biology, University of Colorado, Boulder, CO 80309-0334, USA

The influence of sexual selection on the mating system of a cockroach, *Nauphoeta cinerea*, will be described. Socially dominant males in a hierarchy mate more frequently than expected by random chance. Increased mating success is in part a result of active female mate choice among males. Females discriminate among males on the basis of pheromonal differences. These pheromonal differences also predict future male status. Females can and do discriminate among socially naive males. Females can perceive differences in pheromones without comparing among males. Behavior reflecting mate choice is consistent across generations; preferred males tend to produce preferred sons. Significant heritability exists for sexually selected behaviors. These behaviors reflect differences in male produced pheromones. Thus, sexual selection has affected the evolution of the mating system of *N. cinerea*. Pheromones are used to signal male quality.

CHEMICAL TRAITS IN SEXUAL SELECTION OF ROVE BEETLES (*ALEOCHARA SSP.*, COL.: STAPHYLINIDAE).

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Females of *A. curtula* produce (Z)-7-heneicosene and (Z)-7-tricosene as close range aphrodisiac pheromones, which are also used by males of weak physiological condition for chemical mimicry in order to avoid intermale aggression. Females, however, repulse mating attempts of those males, which emit the mimicking female sex pheromone (young, starved or multiply mated). Males, which were artificially contaminated with the blend of the female sex pheromone, were also not accepted for copulation. Thus, females select males, which (1.) are able to adjust their pheromone titer according to their physiological status, (2.) are capable of defending a territory at carrion, and (3.) transfer a large spermatophore, which provides sperm, nutrients and a plug with antiaphrodisiac pheromones for prevention of further copulations. Females do not select for male body size, except that physiological condition and pheromone status of small males are more affected by starvation and multiple copulations than in large ones. In comparison, *A. lata* and *A. bilineata* living in different habitats exhibit male aggression and female choice to a lower extent. In the latter species, the pheromone information is not sex specific.

DIET RELATED COURTSHIP SUCCESS IN THE ORIENTAL FRUIT MOTH - A CASE OF FEMALE CHOICE SEXUAL SELECTION. Christer Löfstedt*, Neil J. Vickers, and Thomas C. Baker, Department of Ecology, Lund University, Helgonav. 5, S-223 62 Lund, Sweden.

Sequestration, into the hairpencils, of the most behaviourally active courtship pheromone component, ethyl *trans*-cinnamate, in male *Grapholita molesta* (Busck) results in a significantly increased mating success over control males. A significantly greater proportion of displays made by ethyl cinnamate-treated males to calling females resulted in female movement towards the male. Once moving, the female touch to the male abdominal tip, necessary for coupling to occur, was likely. Females attracted to ethyl cinnamate-treated males moved significantly faster than females attracted to control males. The biological significance of these findings and the actual sequestration of ethyl *trans*-cinnamate in the wild are discussed.

ACTIVITY RHYTHMS OF THE SUBTERRANEAN TERMITE *ANACANTHOTERMES VAGANS* (HAGEN) IN KUWAIT DESERT. F. T. Abushama* and W. A. Al-Houty, Department of Zoology Faculty of Science, Kuwait University, P.O.Box 5969, Safat 13060, Kuwait.

Seasonal field records of the foraging activity of the termite *Anacanthotermes vagans* have indicated two yearly peaks; one in February and the other in September. There was a positive correlation between activity and soil moisture content. The highest diurnal activity was at midnight and early morning hours in both summer and winter. In spring the time of highest activity was reversed to take place at mid-day, afternoon and early evening. Laboratory tests demonstrated that individual workers are active most of the day and were not naturally entrained to photoperiods

CIRCADIAN ACTIVITY AND SOCIAL SYNCHRONIZATION IN CAPE HONEYBEES. B. Frisch, Institut für Bienenkunde (Polytech. Ges), FB Biologie der Universität Frankfurt, Karl-von-Frisch-Weg 2, D-6370 Oberursel, FRG.

The honeybee is a well-known example for the importance of the circadian system. This is the basis of the honeybee's sun compass orientation and of the training ability of bees with respect to time. However, little is known about the qualities of the circadian system with respect to individual bees and of the activity of colonies.

Under constant conditions individual bees and colonies show well pronounced cycles of activity and rest with periods that slightly differ from 24 hours. In colonies, common times of activity and rest were maintained over several weeks, and this would seem to indicate that the activity state of the individual members is synchronized. This view is strengthened by experiments in which individual bees were withdrawn from their colony and tested simultaneously but in separate cages. The activity rhythms of the isolated bees drifted and were no longer in synchronization with the colony-rhythm.

The data support the conclusion that the activity rhythm of a colony is due to mutual coupling of individual bees. Thus, social synchronization is - at least under constant conditions - an important factor in coordinating the activity cycles of numerous individuals in order to form a common colony output.

SELECTION OF LEARNING BEHAVIOR INFLUENCES LABOR DIVISION IN HONEYBEE COLONIES. Ch. Brandes, Institut für Tierphysiologie/Neurobiologie der FU Berlin, Königin-Luise-Str. 28-33, D-1000 Berlin 33, and Institut für Bienenkunde, Karl-von-Frisch-Weg 2, D-6370 Oberursel, FRG.

Cape honeybees (*Apis mellifera capensis*) were selected for good and poor learning. These lines differ in several associative and non-associative learning tests but do not show differences in activity or motivation. To investigate whether selected behavior has an influence on the organization of colonies we compared good and poor learners in an observation hive. One colony, which contained marked worker bees of three strains with significant differences in learning scores, was observed with respect to tasks frequently occurring in colonies, e.g. inspecting larvae, comb building, foraging, feeding nest-mates. The lines differed significantly in that good learners performed these tasks more frequently than poor learners. Therefore, it is assumed that labor division is not only dependent on age distribution and other environmental factors but is also influenced genetically.

AGE POLYETHISM, ENZYME ACTIVITY AND JUVENILE HORMONE TITRE IN HONEYBEE, *Apis mellifera* L. H. Sasagawa*, ¹Y. Kuwahara and ²M. Sasaki, Inst. of Agr. & For., Univ. of Tsukuba, Tsukuba, Ibaraki 305 Japan, ¹Inst. of Appl. Biochem., Univ. of Tsukuba, Ibaraki 305 Japan, ²Lab. of Entomol., Fac. of Agr., Tamagawa Univ., Machida, Tokyo 194 Japan.

Age polyethism of characteristic honeybee worker is suggested to be governed by a progressive increase of juvenile hormone III (JH) titre of worker bee along with age. Previous studies suggested that JH regulates physiological processes associated with age polyethism, however, the direct relation of JH to behavior were not confirmed and these hypothesis is not sufficiently evidenced, because of no handy and sensitive method ever being available for determining JH titre of individual workers engaging in a known labor. The present paper deals with two topics; 1) JH titre in haemolymph, after hexane extraction, was determined by HPLC (at 217nm) on a micro column (CN-SiO₂) eluted with 0.6% butanol-hexane, using thymol as internal standard. The unexpectedly large amount of JH was found in bee haemolymph. In summer bee, day 0 worker possessed 0.05ng/μl haemolymph (detection limit), day 26 forager 7.64ng/μl, and its titre increased with age. Seasonal change of JH titre was also noticed. 2) α-Glucosidase of the hypopharyngeal gland was enhanced by treated methoprene (JHA) to bee (and also in vitro), and its effect appeared earlier along with increased dosage, indicating JHA stimulated the synthesis of the enzyme. These results also supported the evidence that well-known progressive change of labor of worker honeybee may related to JH titre.

THE EFFECT OF BEHAVIOURAL STATUS ON DETOXIFYING ENZYME ACTIVITY IN WORKER HONEY BEES (HYMENOPTERA: APIDAE).

M.J. Smirle* Department of Biological Sciences, Simon Fraser University, Burnaby, B.C. V5A 1S6 Canada, and G.E. Robinson, Department of Entomology, The Ohio State University, Columbus, Ohio 43210-1220 U.S.A.

Activities of glutathione S-transferase were measured in worker honey bees of known age and behavioural caste. Groups of workers performing either nursing or foraging duties were obtained from one specially manipulated colony to give six test groups: 7, 14, and 21-day nurses, and 7, 14, and 21-day foragers.

Enzyme activities were similar in all groups with the exception of 21-day foragers, which had significantly elevated activity. Two possible explanations for this phenomenon are: 1) increased activities in foraging workers are triggered both by age and task, and 2) elevated enzyme levels are suppressed by a continuation of nursing duties.

FORAGING EFFORT AND LIFE SPAN IN WORKERS OF THE HONEYBEE *APIS MELLIFERA* L. Th. J. Wolf* and P. Schmid-Hempel, Zoolog. Institut der Universität, Rheinsprung 9, CH-4051 BASEL, Switzerland.

Energetically low-cost foraging strategies such as found in nectar-collecting workers of the honeybee are considered to be adaptive if foraging effort reduces life span. We tested whether such a reduction results by experimentally manipulating foraging activities for individual workers under natural conditions. In a first test, we reduced the daily time individual workers could forage by controlling the entrance of an observation hive. In a second experiment, foraging activity was experimentally increased. Here, we attached different permanent extra loads of varying weights onto the bees' thorax. While a reduction did not lead to an increase in life span (first experiment), there was a significant reduction with an increase in work load (second experiment). The results are discussed with respect to foraging strategy and life-time fitness.

THE EFFECTS OF SWARM TYPE, POPULATION SIZE, AND DATE OF ISSUE ON TEMPORAL DIVISION OF LABOUR IN THE HONEY BEE, APIS MELLIFERA L. K. Naumann* and M.L. Winston, Department of Biological Sciences, Simon Fraser University, Burnaby, B.C., Canada V5A 1S6.

The relationships between temporal division of labour and swarm population size, date of issue, and swarm type were investigated in prime swarms and afterswarms of honey bees. Workers in prime swarm founded colonies began foraging at earlier ages than workers in colonies founded by afterswarms. Within swarm types, there was no relationship between mean age at first foraging and swarm population size but there was a correlation with the relative date of issue.

THE EFFECTS OF SWARMING AND DIFFERENT LEVELS OF MANAGEMENT ON COLONIES OF THE HONEY BEE, APIS MELLIFERA L. (HYMENOPTERA: APIDAE). D. Howpage*, and M.L. Winston, Department of Biology, Simon Fraser University, Burnaby B.C. Canada V5A 1S6.

Population, brood area, and colony weights were measured 5 times at 3 week intervals, and honey yield was recorded in three types of colonies: managed, unmanaged with swarming, and unmanaged without swarming.

Colonies that produced swarms had significantly higher initial brood areas and worker populations than did the other two colony types. Later in the season (during the honeyflow), colonies which produced swarms had significantly less brood area and worker population, but showed no significant reduction in honey production.

By the end of the season (August), colonies from the three types of treatments were indistinguishable in all characteristics measured.

THE INFLUENCE OF QUEEN-PRODUCED MANDIBULAR PHEROMONES ON THE INHIBITION OF QUEEN REARING IN THE HONEY BEE APIS MELLIFERA L. M.L. Winston*, K.N. Slessor, L.G. Willis, K. Naumann, H.A. Higo, M.H. Wyborn, L.-A. Kaminski, Department of Biological Sciences, Simon Fraser University, Burnaby, B.C., Canada V5A 1S6.

In this study, we examined the role of a new, five-component synthetic blend of queen honey bee mandibular gland pheromones in the inhibition of queen rearing. The five-component blend was superior to both mandibular extract and decenoic acid combinations, but was not as active as a live queen, indicating that other, non-mandibular substances are involved in the suppression of queen rearing.

INDUCTION OF 9ODA (QUEEN SUBSTANCE) SYNTHESIS IN THE IMPLANTED WORKER MANDIBULAR GLAND IN THE QUEEN HONEYBEE, APIS MELLIFERA

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9-Oxodec-2-enoic acid (9ODA) is never synthesized in worker honeybee in a usual queenright colony. When the queen is lost, however, workers switch their physiological condition and some of them begin to synthesize queen substances. Actually one laying worker had 59µg of 9ODA in her mandibular gland (MdGld). This means that the enzyme system responsible for the 9ODA synthesis in MdGld may be activated under particular factor(s) even after the caste has been destined to be worker.

Thus we hypothesized the presence of a blood born hormone-like factor, probably from brain, which triggers the switch-over of MdGld function from worker type to queen type. This was proved by implanting a MdGld of newly emerged worker into the gena of queen. For example, one of the worker MdGld implanted synthesized 1µg of 9ODA and other associated fatty acids during 9 days.

CAN PHEROMONES HELP IN UNDERSTANDING AND CONTROLLING HONEY BEE SWARMS? J.O. Schmidt* and S.C. Thoenes, Carl Hayden Bee Research Center, USDA-ARS, 2000 E. Allen Road, Tucson, AZ 85719, U.S.A.

Pheromones control most activities within honey bee societies including reproductive swarming. We have used components of the Nassanov gland secretion to attract scout bees and swarms to man made nest cavities and to study the ecology of honey bee swarms. These studies have focused on: 1) developing an inexpensive, effective, durable artificial nest cavity (swarm trap); 2) surveying the amount and phenology of swarming in Tucson, AZ; 3) the preference of swarms of Africanized honey bees for various nest cavity sizes; and 4) the ecological preferences of Africanized honey bee swarms in Guanacaste, Costa Rica. The best artificial nest cavity consists of a 31 liter wood pulp based container with a slow release formulation consisting of equal amounts of geraniol, the citral isomers, and geranic + nerolic acids. Honey bees in Tucson, AZ swarm strongly during late March to May with peak times of activity within this period varying dramatically among years. In Guanacaste, honey bee colonies and swarming are highly ecologically dependent with strong preferences for nesting near sources of permanent water. The use of pheromones for biological control of honey bee is presented.

PALYNOLOGICAL ANALYSIS OF DIET BREADTH BY HONEY BEE COLONIES IN THE SONORAN DESERT (1980-87). S.L. Buchmann*, and M.K. O'Rourke, USDA-ARS Carl Hayden Bee Research Center, Tucson, AZ, USA 85719 and Department of Geosciences, University of Arizona, Tucson, AZ, USA 85721.

Data are presented for weekly and annual amounts of pollen harvested by managed Apis mellifera colonies living in a diverse upper bajada community near Tucson, Arizona. Pollen influx was also correlated with annual precipitation and the Palmer drought severity index. Pollen trapping (OAC type which harvests 65% of incoming corbicular pellets) yielded from 13.5 to 38 kg annually from these colonies, and calculated total pollen harvested per colony averaged 43.8 ± 13.6 kg yearly. Over a seven year period the colonies collected pollen from 30 to 45 plant taxa, indicating their use of 5 to 10% of the local flora as foodplants. Only 10 to 15 angiosperm species contributed over 90% of the annual colony diet breadth. Major pollen sources for colonies were: c.f. Aster, Prosopis, Liliaceae, Eucalyptus (exotic), Ambrosia, Simmondsia, Larrea and Phoradendron. Anemophilous plant species contributed 5 to 28% of the annual diet, while exotics (ornamentals) accounted for 10 to 24% annually. Palynological analyses of diet selection from debris middens below feral Apis colonies, and propolis and old comb, are also presented for other sites within the Sonoran desert of Arizona.

DIETAL EFFECT AND BEEMILK PRODUCTIVITY WITH THE POLLEN
SUBSTITUTE IN A HONEYBEE COLONY: EFFECT OF FEEDING LOCATION
WITHIN THE HIVE

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Feeding pollen substitutes (PS) is important in managing the honeybee colonies during the pollen-deficient seasons. Many kinds of PS were developed but the effect of feeding location within the hive has not been analysed in detail. We compared the "brood area feeding" vs. ordinal "top bar feeding" with PS (soy protein, yeast and sugar with or without vitamins). Following criteria were used: 1) consumption of PS, 2) degree of development of hypopharyngeal glands, 3) acceptance rate of artificial queen cell cups, 4) amount of royal jelly in the queen cells, and 5) queenliness of the resultant queens. With the all five criteria the brood area feeding gave better results. There was notable differences in the composition of free amino acids and minerals between royal jelly from PS and from control pollen diet. Nevertheless the queens reared in the colony isolated for more than 18 days from natural pollen diet had normal queen characters.

MARCHALINA HELLENICA (GENNADIUS) (HOMOPTERA : MARGARODIDAE)
A USEFUL INSECT OF APICULTURE IN GREECE. L.A. Santas, Lab.
of Apiculture - Sericulture. Univ. Col. of Agric. Sciences
of Athens, GR - 118 55 Votanicos, Greece.

More than 60% of the honey production in Greece derives from the honeydew of the scale M. hellenica. This scale lives on pines in all pine forests of Greece. The beekeepers make use of this honeydew by bringing their hives at the proper time into these pastures.

The insect has one generation per year and the production of honeydew is abundant from July to next spring. The bees collect the honeydew only in August, September, October and next March and April.

The scale is appeared in low population level some years. Insecticides do not applied in pine forests. It seems that the parasites, the predators and the climatological conditions keep some times the scale population low. This influences the honey production in Greece.

THE BIOLOGY OF *AUGOCHLORELLA STRIATA* (HYMENOPTERA: HALICTIDAE: AUGOCHLORINI) AT THE NORTHERN LIMIT OF ITS RANGE. L. Packer, Department of Biology, University of Calgary, Alberta, Canada T2N 1N4.

The range of *Augochlorella striata* extends further north than any other member of the tribe Augochlorini. Over 300 nests of this species were excavated at Irish Cove, Cape Breton Island, Nova Scotia during the summer of 1987. This is the most northern locality known for the species. Foundress females begin foraging in mid June. Approximately 8 brood cells are provisioned before a lapse in activity occurred in July. When the first offspring emerged, their brood cells were reused if the foundress was still alive. An average of 3 additional offspring were produced at this time. Before reactivation, the brood was heavily male biased ~ 3:1, after reactivation it was heavily female biased ~ 1:3. Approximately 50% of nests had a female as the first offspring produced. Approximately 50% of reactivated nests had one (rarely two) daughters that functioned as a worker. Most workers mated but none had ovarian development. This population contained both solitary and eusocial nests. This mixed strategy appears well suited to a marginal environment where the season is sometimes too short to accommodate both a worker and a reproductive brood.

SOCIAL BIOLOGY OF WEST INDIAN SWEAT BEES (HYMENOPTERA: HALICTIDAE). George C. Eickwort, Department of Entomology, Cornell University, Ithaca, New York 14853, U.S.A.

Nest excavations and dissections of foraging bees have been conducted for most species groups of Greater Antillean Halictidae. The predominant pattern is primitive eusociality or semisociality, with small colonies and weakly defined castes. Large colonies with castes occur only in the recent immigrant *Halictus ligatus*. Communal associations occur in *Agapostemon* and one species group of *Dialictus*. Solitary nesting is not a characteristic of successful species groups. Social behavior is similar to that of mainland sweat bees in the Neotropics. No unique patterns of social behavior have evolved in the Greater Antilles, despite the absence of many nest parasites and predators and competitors like stingless bees.

BEHAVIOUR AND DENSITY OF POLLINATORS ON SAINFOIN

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The density and efficiency of bumble bees, honey bees, and alfalfa leafcutter bees on sainfoin, *Onobrychis viciaefolia* Scop., grown in southern Alberta, Canada were studied. Six species of bees were identified as pollinators with alfalfa leafcutter bees comprising 56% of the observations, honey bees 40%, and bumble bees 4%. The density of flower bloom over the season can be described as curvilinear. The mean number of flowers per raceme decreased over the season. The rate of foraging per pollinator species from flower to flower varied and is described by multiple regression models. Julian date, hour in day, and flower density are the independent variables. More than 90% of the bees visited 3 or fewer flowers per raceme when 60% of the racemes had 3 or more flowers available for pollination. The bees foraged on sainfoin for about 12 h per day and average bee density increased with the corresponding flower density. A theoretical approach used to predict the bee populations required to pollinate varying flower densities shows that the population required of bumble bees is about two-thirds that of the honey bees or alfalfa leafcutter bees which are similar.

NESTING BEHAVIOR OF TWO SPECIES OF LEAF-CUTTER BEES AT THE ELF COMMUNICATIONS SYSTEM FACILITY IN NORTHERN MICHIGAN (HYMENOPTERA: MEGACHILIDAE). K. Strickler, Dept. of Entomology, Michigan State University, East Lansing, MI, USA, 48824.

Nest architecture, emergence and overwintering survivorship, and time to collect leaf pieces for *Megachile inermis* and *M. relativa* are being monitored at four sites in northern Michigan to determine whether Extremely Low Frequency electromagnetic fields affect nesting behavior of these bees. The Michigan facility began intermittent operation in 1986 at low power levels. While differences between sites have been detected in such factors as cell lengths, proportion of the nest devoted to reproductive cells, sex ratio of emerged bees, and time to collect a round leaf piece, these differences cannot be attributed to ELF electromagnetic fields. Monitoring of these nesting parameters is continuing in 1988 with the ELF antenna at full power.

NEST DEFENSES OF MALAYSIAN STINGLESS BEES (HYMENOPTERA: APIDAE). L.K. Johnson* and S. Appanah, Department of Biology, University of Iowa, Iowa City, Iowa USA 52242 and Forest Research Institute of Malaysia, Kepong, Selangor, Kuala Lumpur, Malaysia.

Malaysian *Trigona*, like other stingless bees, build species-specific nest entrances, and have species-specific nest defense behaviors. Our systematic survey of the defenses of stingless bees in Malaysia included a daily survey for enemy attacks, all-day monitoring of nest traffic to estimate relative colony sizes, and measurement of entrance features, nest defense behaviors, and responses of introduced intruders to nest entrances of various types. The principal enemies were ants, such as *Oecophylla*, but single *Trigona* raiders were also seen. All bee species at least sometimes attacked experimentally introduced ants or bees. In addition, all nest entrances were at least slightly sticky with resin at the point of entrance. Yet there were major differences among the species, especially in regard to nest crypticity, the importance of mass attack of enemies, and the profligacy of use of sticky resin as a defensive tool. We hypothesize that the nest defenses that bees may use are constrained by species-specific factors such as colony size and foraging behaviors that influence success in the collection of tree resin, a scarce resource.

EVIDENCE FOR REPRODUCTIVE COMPETITION AMONG MALE STINGLESS BEES (HYMENOPTERA: APIDAE). D. W. Roubik, Smithsonian Tropical Research Institute, Apartado 2072 Balboa, Republic of Panama

Studies on male stingless bees treat <10% of major supraspecific groups but suggest diverse behavior and ecology. Males of several matrilineal groups occur in nests of stingless bees and potentially compete for food and mates. Males are produced by the queen and/or workers. Competition begins among larvae, only one of which will emerge from multiple worker-laid eggs placed with the queen's egg in a single brood cell. Adult males receive proteinaceous food only from older workers, thus potentially from their own mother. Males form aggregations that await virgin queens 1) near the parent nest; 2) near an established conspecific nest, or 3) at a new nest of an incipient colony. Males probably find incipient nests by following workers. Male aggregations contain a few to several thousand bees from multiple colonies. *Scaptotrigona pectoralis* was found to form potential male leks of several thousand at 5 m from nests. A few dozen to a few hundred males might be found in their natal nest but are said to leave after a few weeks. I found a nest of *Scaptotrigona barrocoloradensis* containing 3470 workers but 1731 males—likely including those of other colonies. Since meliponine males sometimes help in nest construction, ripen honey, forage nectar at flowers and produce wax, they have traits that could allow them to enter host nests. Adult male stingless bees display no apparent aggressive devices or traits. This does, however, overlook possible repellent odors or other chemicals about which there is little information.

THE COLONY CYCLE AND BROOD COMB DEVELOPMENT IN THE STINGLESS BEE, *TRIGONA TERMINATA* SMITH (HYMENOPTERA: APIDAE). S.G. KHOO, Department of Zoology, University of Malaya, 59100 Kuala Lumpur, Malaysia.

The developmental period of a worker is about 38 days while that of a queen is around 165 days. Queen cell construction (as well as oviposition) occurs every few days except for periods of 3-4 weeks in every 2-2½ months when no queen cells are formed. Queen cells are not produced on the uppermost combs of a comb-spiral. Adult males frequently occur in the nest in small numbers most of the time but may increase at certain periods. The nature of brood comb development and the health of the queen may have a bearing on the production of males and gynes. The regular occurrence of two advancing fronts on the comb-spirals at certain periods in the colony cycle enables oviposition by workers and the production of males. In view of the long developmental period of a queen, the regular production of queen cells and males thus ensures queen superseding and the survival of the colony should the need arise.

PARASITIC FLIES AS POTENTIALLY IMPORTANT SELECTIVE FACTORS FOR THE LIFE CYCLE OF THEIR BUMBLEBEE HOSTS. P. Schmid-Hempel *, C. Müller, R. Schmid-Hempel and J. Shykoff, Zoologisches Institut der Universität Basel, Rheinsprung 9, CH-4051 Basel, Switzerland.

We have studied populations of parasitic flies (Conopidae, Diptera) and their bumblebee hosts (Apidae, Hymenoptera) at locations in Central Europe. Incidence of parasitization was found to be substantial (average: 16% of workers, 12% of males), depending on sex, species, and month. Infestation causes a drastic reduction in worker life span and leads to aberrant behaviors. Furthermore, important characteristics of the life cycle in host populations (e.g. the temporal pattern of worker and male production) are found to be related to the degree of parasite infection. We theoretically investigate whether such shifts in reproductive timing could be an adaptive response to minimize expected fitness costs associated with unavoidable parasitization. Our studies suggest that parasitic flies exert substantial ergonomic stress on bumblebee colonies and may therefore be important selective agents for the evolution of life cycles in their hosts.

SOCIALITY IN A SPHECID WASP, *MICROSTIGMUS COMES*: NEW INSIGHTS FROM GENETIC ANALYSIS OF A NATURAL POPULATION. R. W. Matthews* and K. G. Ross, Department of Entomology, University of Georgia, Athens, GA 30602 U. S. A.

Although *M. comes* is known to exhibit overlap of adult generations and cooperative brood care, conclusive evidence for the third criterion of eusociality, reproductive division of labor, has been lacking. We collected and individually weighed the entire adult population from colonies after the colonies' spatial relationships were mapped. Three electrophoretic markers that appeared to be in linkage equilibrium (hence, independent markers) were scored from the thorax of each wasp. For 88 nests we obtained an overall estimate of nestmate female relatedness of $r=0.672$. The pattern of genotypes found within individual nests was consistent with the hypothesis that colonies consist of simple family groups. Moreover, skewed genotype ratios implicated a single female as the putative mother of the other wasps. This female also proved to be the heaviest wasp in the colony, suggesting incipient caste development. Microgeographic genetic structure of the population was found to parallel the hierarchical spatial structure, with females from nests on the same plant having r values lower than r values among nestmates, but higher than those of females from nests found on adjacent plants.

NEONTOCRACY IN A NEOTROPICAL SOCIAL WASP, *POLISTES MAJOR* (HYMENOPTERA: POLISTINAE). S.A. Cameron, Department of Entomology, The Ohio State University, Columbus, Ohio 43210-1220, USA

The relationship between age and dominance in the primitively social wasp, *Polistes*, is thought to reverse from temperate to neotropical species. While the temperate-zone spp. have a gerontocratic (dominance passes to the oldest) dominance order, in tropical spp. it appears that a neontocracy (dominance passes to the youngest) may prevail. *Polistes major* in Costa Rica is consistent with this north-south trend. In *P. major* females could be predicted to become replacement queens (egg layers) by the following: (1) young age, (2) low foraging rate, (3) being the object of high aggression by the queen, and (4) exhibiting the highest rates of aggression toward other workers. Supersedure by a dominant could be predicted by its (1) attacks against the queen and (2) abdominal rubbing over the nest surface and brood. Dominance was established by egg laying.

NON-SPECIALISTS ENHANCE WORK EFFICIENCY IN A TROPICAL SOCIAL WASP. R.L. Jeanne, Department of Entomology, University of Wisconsin, Madison, WI 53706.

Nest construction behavior in *Polybia occidentalis* involves coordination of 3 interdependent tasks--water foraging, pulp foraging, and building--performed by 3 groups of workers. This task specialization yields a 40% saving in foraging trips when compared to non-specialization. In large colonies nest construction appears to run smoothly: delays are short, task switching by "generalist" workers is rare, and efficiency is high. By comparison, in small colonies delays are longer, switching events are much more frequent, and efficiency is significantly less. A simulation of the system based on queueing theory showed that small colony size leads to lowered efficiency due to longer waits in queues, but that allowing task switching by non-specialized workers ameliorated the loss. This suggests that although specialization in the 3 tasks leads to greater efficiency, there is a role for generalists in fine-tuning the colony's allocation of worker numbers among the 3 tasks.

CLADISTICS AND COMPARATIVE SOCIAL BEHAVIOR OF THE STENOGASTRINE WASPS (HYMENOPTERA: VESPIDAE). C.K. Starr, Dep't of Entomology, Smithsonian Institution, Washington, DC 20560 USA

Recent advances in the systematics of the Stenogastrinae, combined with what is known of their diverse social habits, allow new insight into patterns of social evolution within the group. Attention is given here to two problems:

1. Evolutionary radiation of nest-structure within the subfamily as a whole.
 2. Founding-group size and other features of colony organization in the genus *Parischnogaster*.
- The second problem, especially, has given rise to new testable hypotheses.

L'OCCURENCE DE COPTOTERMES HAVILANDI HOLMGREN (ISOPTERA: RHI - NOTERMITIDAE) DANS DOCUMENTS. D. Pamplona* et J.R. Pujol-Luz, Department d'Entomologie, Museu Nacional, Rio de Janeiro, RJ, Brésil, CEP 20942.

Une partie des documents de la Firme Light-Rio qui se trouvent déposés dans un vieux bâtiment en face de la plage Pintangueiras, à l'Ilha do Governador, s'encontre dommagée par des insectes et microorganismes. Entre les insectes celui qui nous a le plus retenu l'attention est Coptotermes havilandi, une espèce très commune dans l'état de Rio de Janeiro, et ayant une période d'envol établie d'Août à Septembre. Cette espèce a détruit une partie considérable des volumes et probablement infeste tout l'immeuble. Un des embranchements du nid, localisé dans un dépôt, est notable par son extention et par les dommages provoqués au documents. Cet embranchement, d'à peu près 1,30m de haut, a formé, dans les documents qui se trouvaient empilés sur le sol, une substance cartonneuse caractéristique de la présence de l'animal. Pour la construction de ce nid, ils utilisèrent une grande quantité de terre qu'ils transportèrent à l'intérieur des volumes, ce qui a endommagé pratiquement tous les documents et a favorisé l'installation d'insectes typiques de sol, comme d'autres Arthropodes et Annelidés.

NESTING BEHAVIOUR OF THE SOCIAL WASP ROPALIDIA VARIEGATA. T. Antony Davis, J.B.S. Haldane Research Centre, Nagercoil 4, Tamilnadu, India.

Observations were made on 20 colonies comprising 155 nests of the social wasp, Ropalidia variegata (Smith) (Hymenoptera: Vespidae) at Calcutta and in Kanyakumari district of Southern India. Ropalidia was found to nest on a variety of dicotyledonous leaves and in two monocot plants, banana and coconut. The structure of nests founded on the two groups of plants vary statistically significantly. Nests on leaves of banana and coconut have two or three rows of cells each. This adaptation copes with the changing position of the sitting leaves and ensures stability since its only substratum is provided on the first cell. Cannibalism is common in Ropalidia which in this species is clearly not motivated by lack of food. The founding mother builds the nest by herself and continues to lay an egg in each cell. To feed the larvae, workers from other colonies arrive until enough workers emerge from her own nest/colony. In summer, an egg develops into an adult in about a month, but in winter in about 3 months. Pupal period varies from 29 to 9 days between winter and summer, accounting for a 300% acceleration in biological activity.

THE MECHANISMS AND ENERGETICS OF TEMPERATURE REGULATION IN ARMY ANT BIVOUACS. N.R. Franks, School of Biological Sciences, University of Bath, Bath BA2 7AY, U.K.

The bivouac-nests of the army ant, Eciton burchelli, are composed of the bodies of living workers who form a basket-like structure to cradle the whole colony including the queen and her brood. My recent studies show that the accuracy of temperature regulation at the core of the bivouac equals or even surpasses that of swarms of honeybees. After discussing the mechanisms by which this thermoregulation is achieved, I will consider how the energetics of this behaviour may impose constraints on the distribution and abundance of army ants.

INFLUENCE OF NESTMATE RECOGNITION ON THE ATTRACTIVENESS OF QUEENS TO WORKERS IN THE ARGENTINE ANT, *IRIDOMYRMEX HUMILIS* (MAYR) (HYMENOPTERA: FORMICIDAE). L. Keller*¹ and L. Passera². 1) Museum of zoology, Palais de Rumine, C.P. 448, 1000 Lausanne 17, Switzerland. 2) Laboratoire d'entomologie, U.P.S., 118, rte de Narbonne, 38000 Toulouse, France.

In social insects, queens produce pheromones which make them highly attractive to workers. This attractiveness of queens to workers and the ability of workers to discriminate nestmates from other conspecifics are two factors playing a major role in the social organization of social insects. Data will be presented to demonstrate that a phenomenon of recognition is superimposed on the attraction of workers to queens. Workers are significantly more attracted to nestmate queens than to non-nestmate queens. This difference is based on learning of queen odor by workers, probably at the time of their emergence. Comparison of experimental colonies also showed that workers were significantly less attracted to queens in polygynous colonies than in monogynous colonies. This difference in the level of attraction of workers to queens certainly resulted from a lower efficiency of nestmate recognition in polygynous colonies. These results are discussed with regard to the social organization of ants.

ISOLATION AND MULTIPLE BEHAVIOURAL BIOSASSAYS OF TRAIL PHEROMONE FROM EXCISED STERNITES OF *RETICULITERMES HESPERUS* BANKS (ISOPTERA: RHINOTERMITIDAE). J.K. Grace*, Faculty of Forestry, University of Toronto, Toronto, Ontario, Canada M5S 1A1; D.L. Wood and I. Kubo, Department of Entomological Sciences, University of California, Berkeley, California, U.S.A. 94720.

Compound(s) inducing trail-following behaviour were isolated and partially purified by solvent extraction of the fourth and fifth abdominal sternites (morphological site of the sternal gland) excised from *R. hesperus* workers, and sequential fractionation by high-performance liquid chromatography (HPLC), and gas-liquid chromatography (GC). Behavioural bioassays confirmed that both initiation of trail-following (individual recruitment) and orientation along trails are induced by a single HPLC fraction. Additional behavioural assays on artificial trails drawn with solvent extracts of *R. hesperus* sternites demonstrated that initiation of trail-following, distance traveled without pausing or diverging, rate of locomotion, and directional orientation are dependent upon pheromone concentration.

CHEMICAL MIMICRY IN A PARASITOID, *ORASEMA* SP., (HYMENOPTERA: EUCHARITIDAE) OF FIRE ANTS. D.P. Jouvenaz*, R.K. Vander Meer, and D.P. Wojcik, USDA/ARS, P. O. Box 14565, Gainesville, FL 32604.

A Eucharitid wasp, *Orasema* sp., is ectoparasitic on pupae of the fire ant, *Solenopsis invicta* Buren, in Brazil. Integration of the parasites into the host colony apparently is achieved by chemical mimicry. The profile of cuticular volatiles of immature hosts and parasites are identical. No parasite-specific hydrocarbon components are observed in immature wasps; however, after leaving the nest as adult parasites a species-specific profile was detected. We suggest that the wasp passively acquires the colony odor while living as an ectoparasite or, as pupae, merely in close contact with the brood. As adults, the wasps biosynthesize their own specific blend of cuticular compounds, retaining only residual amounts of host components. Visual and behavioral mimicry does not appear to play a role in integration of *Orasema* sp. in fire ant colonies. Wasp pupae are readily adopted by conspecific fire ant colonies.

MUTILATION CONTROLS REPRODUCTION AMONG THE WORKERS OF *DIACAMMA AUSTRALE*, A PONERINE ANT WITHOUT THE QUEEN CASTE. C. Peeters* and S. Higashi, School of Zoology, University of New South Wales, Sydney, Australia; Graduate School of Environmental Science, Hokkaido University, Sapporo, Japan

In ants, the mated queens normally reproduce, but in several species of Ponerinae, workers permanently perform the reproductive role. Those workers that become mated lay all the eggs, and several of these 'gamergates' occur in each colony. In *Diacamma australe* however, there is only one mated worker per colony, and she inhibits the ovarian activity of nestmates. When the gamergate is removed, many workers start to lay unfertilized eggs. Since all workers have large ovaries, egg-laying rate is high. The only other ponerine known to have a single gamergate per colony is *Pachycondyla krugeri* (M. Wildman and R. Crewe, Insectes Soc. submitted), but the regulatory mechanism for this system is not understood.

An unusual characteristic of *D. australe* is the occurrence of minute wings in all eclosing workers. These are soon bitten off by the gamergate, who is the only worker to retain hers (also in *D. rugosum*; T. Abe, pers. comm.). Mutilation seldom occurs in colonies without a gamergate, and thus in her absence (following natural death or colony fission), most eclosing workers retain their wings and presumably are able to become mated when males are active.

COMPUTER SIMULATION OF THE POPULATION DYNAMICS OF THE IMPORTED FIRE ANT, *SOLENOPSIS INVICTA*. G.A. Mount, D.G. Haile, and D.F. Williams*, USDA/ARS, P. O. Box 14565, Gainesville, FL 32604.

A comprehensive computer model of the life cycle of the imported fire ant, (IFA), *Solenopsis invicta*, was developed to simulate the effects of major environmental variables on population dynamics of this social insect in various types of habitat. The life cycle of IFA was incremented in the model into weekly age classes and simulations were run with weekly time steps. The model incorporates (1) temperature-dependent development rates for eggs, larvae, and pupae; (2) the influence of habitat type, temperature, and precipitation on survival rates of all stages; (3) the effect of temperature and worker ant density-dependence on feeding rates; (4) density-dependent survival of colony-founding queens; (5) the effect of temperature and 4th instar larvae density on fecundity; (6) the production of alates influenced by temperature and season; and (7) the effect of temperature and precipitation on mating flights.

SOLENOPSIS INVICTA/S. *RICHTERI* HYBRIDS: THEIR OCCURRENCE IN TIME AND SPACE IN THE UNITED STATES. C.S. Lofgren*, and R.K. Vander Meer, Insects Affecting Man & Animals Research Laboratory, ARS, USDA, Gainesville, FL 32604.

Two color variants of the *Solenopsis saevissima* complex were introduced into the southern U.S. in the early 20th century. Originally, they were considered to be 2 forms of a single subspecies, *S. saevissima* var. *richteri*. However, Buren (1972) elevated them to species rank calling the red form *S. invicta* and the black form *S. richteri*. He justified this separation based on lack of evidence for hybridization and consistency of phenotypic characters. More recently, however, we have demonstrated the existence of viable hybrid populations by using biochemical characters (venom alkaloids, cuticular hydrocarbons) and behavioral responses to trail pheromones. Furthermore, biochemical analysis of museum specimens has provided evidence that hybridization has probably occurred since the 2 species first came in contact with each other in the area in and around Mobile, Alabama. Up-to-date distribution records will be presented.

ANTS NESTING NEAR EFFLUENT PONDS OF A NUCLEAR REACTOR IN SOUTHEASTERN IDAHO, U.S.A. P.E. Blom, J.B. Johnson*, Div. of Entomology, Dept. PSES, Univ. of Idaho, Moscow, Idaho 83843 U.S.A., and S.K. Rope, Radiological and Environ. Sciences Lab., U.S. DOE, Idaho Operations Office, 785 DOE Place, Idaho Falls, Idaho 83402 U.S.A.

Nest soils of the harvester ant Pogonomyrmex salinas were sampled in the vicinity of three water effluent ponds and analyzed for gamma emitting radionuclides. Both Cs-137 and Co-60 were found. Relative concentrations of both radionuclides suggest the ants may transport (presumably vertically) soil of higher radioactivity to their nest construction. Ants and nest thatch material of Formica sp. from the same ponds were also sampled and analyzed. Five radionuclides were found associated with the ants and thatching. The Formica were observed tending both aphids and treehoppers on rabbitbrush near the ponds' edge.

PRELIMINARY INVESTIGATIONS INTO NEST-BUILDING BEHAVIOUR IN THE ANT MYRMICA RUBRA L. E.J.M. Evesham, Clayesmore School, Iwerne Minster, Blandford Forum, Dorset DT11 8LL, UK.

Earlier work has shown that when ants are provided with soil, they begin to excavate. Foragers explore the nest before providing cells, of varying designs, to place sorted brood and queens.

A simple nest design is described which was used to see whether the angle of the nest affected nest-building behaviour in the polygynous ant M. rubra. Tests were carried out using nests placed at 180°, 45° and 90° to the horizontal. The shape of the chambers change with nest orientation. The presence of queens appears to influence worker ability to build. Further experiments will investigate the effect of the Earth's magnetic field, number and age of the workers upon ant nest-building behaviour.

CHANGES IN BLOOD PROTEIN LEVELS IN HONEY BEES INFESTED BY THE TRACHEAL MITE, ACARAPIS WOODI (RENNIE) (ACARI: TARSONOMIDAE). L.A. Royce* and G.W. Krantz, Department of Entomology, Oregon State University, Corvallis, Oregon 97331, USA.

Honey bees infested by tracheal mites experienced a significant diminution in hemolymph protein levels, even when infestations were limited to one female. This paper explores possible causes and consequences of this response.

PARASITIC ECOLOGY OF VARROA JACOBSONI ON ADULT WORKER HONEYBEES. K. Takeuchi*, and T. Sakai, Inst. of honeybee Sci. Tamagawa University, Machida-Shi, Tokyo, 194 Japan

The parasitic rate of Varroa mites on adult honeybees was investigated. A sample group was consisted of more than 300 worker bees from each colony.

On inquiry of two hive-body colony in summer, the parasitic rate in the bottom hive (2.3 - 25.2%) was 1.2 - 3.7 times as high as that in the top hive when majority of bees was at the top, and vice versa.

The parasitic rate on the bees in honey stock area was 1.5 - 7.1 times as high as that on the bees in brood area in 6 colonies out of 7 in summer, but 10 - 60% lower in 4 colonies out of 6 in winter.

In April and May, house bees showed higher parasitized rate than newly emerged bees, but the latter was 1.6 - 6.3 times as high as the former from October to December.

The parasitic rate in worker honeybees within 24 hours from their emergence was high, and decreased to 1/5 - 1/10 level if the initial rate after a week, 1/8 - 1/10 level after two weeks. The rate on foraging bees was only 3 - 10% of that on house bees irrespective of seasons.

Transfer rate of the mite between worker bees confined in a petri dish was examined and found as ca. 20% at the maximum, during 24 hours.

VARROASIS, A NEW PROBLEM IN IRANIAN APIARIES. Esmaili Mor-teza, Entomology Department, University of Tehran, Karaj, Iran 31584.

Varroa jacobsoni was first officially reported from Iran in 1985. How this parasite first penetrated this country, is not accurately known. However, it is presumed that either it came in with swarms from the northern bank of the Aras river bordering on the USSR, or it was illegal importation in bee colonies from Turkey. The parasite is spreading all over Iran due to the migratory system of beekeeping, but it is most destructive in the northern provinces. Various chemicals have been tested for control, but systemic compounds such as perysin, Apitol and Fobex Va seem to be most effective.

BEHAVIORAL RESISTANCE MECHANISM OF THE ASIAN HONEY BEE (APIS CERANA) TO PARASITIC MITE, VARROA JACOBSONI. Y.S. Peng, Department of Entomology, University of California, Davis, CA 95616, U.S.A.

Parasitism of Varroa can induce Asian worker bees to perform a series of cleaning behaviors that effectively remove the mites from the bodies of the adult hosts and brood. The mites are injured and killed by the bees and subsequently removed from the hive in a few seconds to a few minutes. The grooming behavior consists of self-cleaning, grooming dance, nestmate cleaning and group cleaning. The European honey bee (Apis mellifera) shows cleaning behavior at low frequency and generally fails to remove the mites from both the adult bees and the brood.

Both water and solvent extracts of the mites can elicit the Asian bee to show a similar behavior response. The observation suggests that the recognition of mite by the Asian honey bee involves olfaction, however, visual factor is not excluded.

In interspecifically mixed colonies of both species of honey bees, the mites on the introduced brood of European honey bee are removed by the adult Asian worker bees. However, other pathological, ecological and behavior factors should be studied in detail before considering the use of interspecifically mixed colonies to control the mite.

COMPARISON OF BIOTECHNICAL AND CHEMICAL METHODS TO CONTROL *VARROA JACOBSONI* (ACARI, MESOSTIGMATA) IN HONEY BEE COLONIES IN THE NETHERLANDS. A. de Ruijter, Research Centre for Insect Pollination and Beekeeping "Ambrosiushoeve", Ambrosiusweg 1, 5081 NV Hilvarenbeek, The Netherlands.

Field experiments were carried out with two biotechnical control methods, i.e. "the caged queen method" and the "trap comb method" and compared with chemical control methods: Perizin (coumaphos) and Apistan (fluvinate). Both the effectivity against the Varroa mites and the short term and long term effect on treated honeybee colonies was determined. Although a substantial number of mites can be removed from the colonies using biotechnical methods, at the moment chemical control is still indispensable to keep the number of mites below the damage level.

A MODEL STUDY ON THE ROLE OF *VARROA JACOBSONI* AS A VECTOR OF BACTERIAL INFECTIONS IN THE HONEY BEE. Z. Gliński*, J. Jarczyk, Honey Bee Research Laboratory Agricultural University and Unit of Insect Pathology M. Curie-Skłodowska University 20-033 Lublin, Poland.

The role of stenophagous ectoparasitic mite *Varroa jacobsoni* as an inducer and vector of viral infections in varroa disease is established, but function of *Varroa* as a vector of bacterial parasites or saprophytes associated with brood, bees and apiary environment needs further studies. Microbiological bioassays with the use of *Serratia marcescens*, a prodigiosin producing indicator bacterium, show clearly that *V. jacobsoni* carries this facultative pathogen of honey bee on body surface, as well as, that it can support the bacterial growth in the alimentary canal of the mite. Almost all mite specimens fed on upright larvae and worker honey bees artificially inoculated with *S. marcescens* by spray, feeding or injections harbour bacterial cells of *Serratia* on body surface and in intestines. The majority of brood and bees died due to *S. marcescens* septicaemia after the contact of the bees with polluted *V. jacobsoni* mites. Since the mite can be polluted with *S. marcescens*, supports bacterial growth in its interior and transmits the indicator bacterium to a recipient host, *V. jacobsoni* serves as a mechanical and biological vector of bacterial parasites from one bee host to another.

THE RESISTANCE MECHANISM OF THE ASIAN HIVE BEE (*APIS CERANA*) TO A BEE MITE (*TROPILAEALAPS CLAREAE*)
Siriwat Wongsiri
Bee Biology Research Unit, Faculty of Science, Chulalongkorn University

The bee mite *Tropilaelaps clareae* is an ectoparasite of the honey bee, *Apis mellifera*. *T. clareae* is a problem to *A. mellifera* which is the imported species for beekeeping industry in Thailand.

Originally *T. clareae* was a parasite of *A. dorsata*, that native in Thailand. But mites do not appear to be a problem with *A. cerana*. We, as well as other scientists have never seen mites or symptoms of their damage on worker bees. A behavioral physiological resistance mechanism of *A. cerana* to the mites (*T. clareae*) has been observed. Mite parasitism induces *A. cerana* to perform a sequence of cleaning behavior that effectively removes the mites from the bodies of the adult host bees. The mites were subsequently killed and removed from the bee hives in a few seconds to minutes. The grooming behavior consists of a self-cleaning behavior, a grooming-dance, a nestmate-cleaning and a group cleaning behavior of nurse bees. Worker bees or nurse bees can also effectively remove the mites from the brood in a few seconds to minutes. The European bee, *A. mellifera* showed cleaning behavior at low frequency and generally failed to remove the mites from both the adult bees and the brood.

#50

THE FORAGING ACTIVITY OF SUBTERRANEAN TERMITES IN KUWAIT DESERT. F.T.ABUSHAMA and W.A.AL-HOUTY*, Department of Zoology, Kuwait University, State of Kuwait.

Termite foraging activity was tested in four localities in Kuwait, using wood baits. *Psammotermes hybostoma* Desneux and *Anacanthotermes vagans* (Hagen) were the dominant species

Two activity peaks were recorded; one in February and the other in September. There was a positive correlation between termite activity and soil moisture content. Nest foci and frequency of bait infestation was determined.

Analysis of the physical and chemical soil properties revealed some relationship between these properties and the termite species domination.

#53

SOCIALITY OF THE GIANT BURROWING COCKROACH, *MACROPANESTHIA RHINOCEROS* SAUSSURE (BLATTODEA: BLABERIDAE) IN AUSTRALIA.

T. Matsumoto, Department of Biology, College of Arts & Sciences, University of Tokyo, Tokyo 153, Japan.

The giant burrowing cockroach, *Macropanesthia rhinoceros* was studied with special reference to familial association in the eucalypt open forests in Queensland, Australia in October and December 1987. 129 burrows were investigated and 47 adults and 86 single nymphs (middle age) were collected in four quadrats (each quadrat is 8m x 4m). 16 families consisting of a group of small nymphs together with an adult pair or a female were found. Overall mean clutch size of family group was 21.5 ± 6.4 . The field evidence presented here shows that the cockroach lives in the family groups and the intimate adult-offspring relationships may continue for a long time.

#51

INTERSPECIFIC AGGRESSION BETWEEN *COPTOTERMES FORMOSANUS* SHIRAKI AND *RETICULITERMES FLAVIPES* (KOLLAR) UNDER LABORATORY CONDITIONS. D.M. Chambers* and P.A. Zungoli, Department of Entomology, Clemson University, Clemson, S.C., U.S.A. 29634-0365

Two laboratory competition/aggression trials were conducted using individuals collected from each of three colonies. The first trial (three replicates) was conducted using cohorts of 50 *R. flavipes* (2% soldiers) vs. cohorts of 50 *C. formosanus* (10% soldiers) held at 27 C and 90% +/- 4% RH. Within 24 h, 94% (range: 38% to 100%) mortality was observed in *R. flavipes* individuals, while only 28% (range: 2.7% to 50%) mortality was observed in *C. formosanus*. Control mortality of *R. flavipes* and *C. formosanus* (held separately in similar containers) was 1.5% (range: 0% to 2.7%) and 1.4% (range: 0.7% to 2.2%), respectively.

The second trial (five replicates) was conducted using a series of one-on-one five minute observational interspecific pairings of soldier vs. soldier, soldier vs. worker, and worker vs. worker. Results indicate that mortality observed in previous tests can be accounted for by the increased interspecific aggression shown by *C. formosanus* individuals. No conspecific aggression was observed in intraspecific one-on-one trials between individuals from different colonies.

#54

SOME ULTRASTRUCTURAL FEATURES OF THE *CAMPONOTUS RUFIPES* PROVENTRICULUS (HYMENOPTERA: FORMICIDAE). F.H. Caetano*, C. Cruz-Landim & R. Hoffmeister, Departamento de Biologia UNESP - 13500 - Rio Claro - SP - Brazil.

The proventriculus of ants show variations more or less typical of each subfamily. More variations occur in the Ponerinae subfamily, than in other subfamilies that are considered to be more advanced. In the Formicinae, one of more advanced subfamilies, the proventriculus presents a complex structure. It is formed by four distinct sepals and has a small expansion in the middle of proventriculus neck. Under TEM the sepals show a longitudinal canal which is not continuous but begins at the top and ends near the distal portion. The lumen of each canal is smooth and surrounded by multidirectional crossbars with small spaces between. This architecture appears to confer more resistance and a considerable weight reduction. Under SEM, this canal shows a communication with the proventriculus lumen. A strong circular musculature surrounds the proventriculus.

#52

ON THE DEVELOPMENT OF MANDIBULAR GLANDS IN *Constrictotermes cyphergaster* WORKERS (ISOPTERA, TERMITIDAE, NASUTITERMITINAE). A.M. Costa-Leonardo* Departamento de Biologia, Av. 24-A Nº 1515, 13 500, Rio Claro - SP, Brazil.

Constrictotermes cyphergaster is a neotropical termite very common in the cerrado of Brasilia. The mandibular glands are exocrine glands observed in all termite species. Their size are not notable in the neuters caste. This research relate a great development of the mandibular glands in the workers caste of *Constrictotermes cyphergaster*. They occupy a great part of the insect head and has a sacular aspect with vacuolar cells. The histological variations of the mandibular glands in different castes are probably related to the glandular function.

#55

THE BROOD AS THE FOCAL POINT OF THE SOCIETY ORGANIZATION: THE CASE OF THE PONERINE ANT *ECTATOMMA RUJIDUM*. B. Corbara*, Y. Leclerc, J.P. Lachaud and D. Fresneau. Laboratoire d'Ethologie et Sociobiologie (UA-CNRS 667), Université Paris XIII, F-93430 Villetaneuse, France.

In the ponerine ant *Ectatomma ruidum* Roger, we have been interested in the brood (eggs, larvae and cocoons) as a mean explanatory factor of social organization in terms of division of labour.

Three complementary approaches concerning this problem are therefore presented:

- a study of brood demography linked to behavioral data in the case of founding queens and during the stages corresponding to the presence of the first workers.
- a study of the dynamics of the brood aggregation phenomena during isolation/reuniting experiments.
- a study of the relationships between social and spatial organization in mature societies leading to the concept of the brood being the focal point.

#56

PERIODS OF ACTIVITY OF *CAMPONOTUS MOROSUS* (SMITH, 1858), FORMICIDAE, DURING AN ANNUAL CYCLE. J.H. Ipinza-Regla*, R. Covarrubias and M.A. Morales. Facultad de Ciencias Veterinarias y Pecuarias. Lab. Zoología e Insectos sociales Universidad de Chile. Casilla 2 Correo 15 La Granja Santiago-Chile.

Daily and annual cycles of activity of *Camponotus morosus* were studied. The place 20 Km. far from Santiago (Chile), is a brushwood environment at the foot hill of the Andes and ecologically corresponds to the semiarid Mediterranean Region. Number of explorers leaving the nest per minute were hourly recorded (06.00-24.00 hours) during an annual cycle (40 times).

It was found that activity of explorers finished before the end of summer. About one per minute left the nest during the annual cycle, having an important increase on November. Activity of explorers was only noticed from 08.00 to 24.00 hours, having two peaks (10-13 hours and at 16.00 hours). Increases of activity during the annual and daily cycles were statistically significant.

Project : DIB 2217 Universidad de Chile

#57

SOCIAL INSECTS IN URBAN ENVIRONMENTS: THE ANTS OF MEXICO CITY. I. López-Moreno*, M. Díaz Betancourt & C. Gutierrez. Instituto de Ecología. Ap.postal 18-845. México 11800 D.F.

Mexico city, the biggest city of the world, has been subject throughout a series of modifications such as composition, distribution and abundance of its native flora and fauna. Insects are common inhabitants of urban ecosystems and provide a contact with nature for people.

For the particular case of social insects, Kondoh (1978) finds that the ants decreases from 17 to 7 species in Tokyo. In this sense, the aim of this survey consists in to develop a diagnostic about the ant species related to the urban trees, as well as to the species that grow in the streets, sidewalks and vacant lots. Likewise it is essential to detect the possible relations between the species richness and some ecological factors.

The study is based in 90 random censuses in Mexico city. The results consist in the taxonomic list of ant species considering its origin, distribution, as well as the use of the space, time and food consumption.

Actually, we have registered a total of 16 ant species which belong to the subfamilies Dolichoderinae, Formicinae and Myrmicinae. Omnivorous species and honeydew feeders were the most abundant groups.

#58

POSSIBILITY OF CUTICULAR HYDROCARBONS AS CHEMICAL CUES OF ANTS FOR RECOGNITION OF NEST MATE, FAMILY AND SPECIES

R. Yamaoka*, M. Fujioka, T. Yoshimura and K. Hayashiya, Department of Applied Biology, Kyoto Institute of Technology, Matsugasaki, Sakyo-ku, Kyoto 606 Japan.

Cuticular hydrocarbons of 42 different species of ant in Japan were analyzed by capillary GC and GC/MS. The cuticular hydrocarbons of the ants mainly consisted of odd carbon number 23 to 35, normal saturated and unsaturated, and branched compounds.

Difference Between;

(Species): The hydrocarbon constituent profiles of all of the ants on GC were completely different except for that of the slave keeping ant *Polyergus samurai* and her slave *Formica japonica*. A similar relationship was observed between the ant *Camponotus kiusiuensis* and a spider living together in the same cavity in a tree branch. These data suggest that the ant may use these chemicals as species recognition cues.

(Caste): No clear difference was observed between queen, males, workers and (soldiers) in the same colony.

(Life Stage): The hydrocarbon profile of the larvae was completely different from that of the adults.

(Colony): In the same species, the different colony members had the same hydrocarbons but the relative intensity between them was slightly different. These data may suggest a role in nest odor.

(Workers in same colony): The difference in the relative intensity was much smaller than that between colonies.

All of the data indicate the possibility that the ants use the cuticular hydrocarbons as semiochemicals to maintain their social structure.

#59

POPULATION, SEASONAL, AND YEARLY POLLEN FORAGING IN *OSMIA LIGNARIA PROPINQUA* CRESSON (HYMENOPTERA: MEGACHILIDAE). R.W. Rust, Department of Biology, University of Nevada, Reno, Nevada, U.S.A. 89557.

Pollen analysis from nest provisions of two sympatric populations of *O. l. propinqua* over a two year period showed a seasonal pattern beginning with *Salix* (Salicaceae) and progressing through *Purshia* (Rosaceae). Population I used significantly more pollen species (5.2 ± 1.7 (S.D.) versus 2.5 ± 0.5) and had larger niche breadths (0.372 ± 0.129 versus 0.203 ± 0.048) in both years than Population II. There was no difference in the percentage of cells with one pollen species (48.3 ± 24.5 versus 55.9 ± 30.6) or in the average number of cells produced (5.7 ± 1.0 versus 5.7 ± 1.3) by the two populations.

The foraging differences resulted from the proximity to the dominant pollens, *Salix* and *Purshia*, to the nesting site. *Salix* was a minimum of 600 meters distance from Population I, but only 300 meters from Population II. *Purshia* was within 200 meters of both populations. The increased distance traveled by Population I bees allowed foraging on alternative pollen sources, *Camassia* (Liliaceae), *Ceanothus* (Rhamnaceae), *Delphinium* (Ranunculaceae), and *Potentilla* (Rosaceae).

#60

ISOLATION AND CHARACTERISATION OF THE INCUBATION PHEROMONE OF BUMBLE BEES.

D.R. Greenwood*, R.P. Macfarlane and P.J. Watts, Biotechnology Division and Entomology Division, DSIR, Palmerston North, New Zealand.

The observations made by B. Heinrich [J. Kans Entomol. Soc., 47:396-404 (1974)] have been extended to include *Bombus terrestris*, *B. ruderatus* and *B. hortorum*. Heinrich reported that broody bumble bee queens appear to deposit an incubation pheromone onto their incipient brood clumps. Adult bees respond to this species-specific pheromone by incubating surfaces impregnated with the pheromone. The active principle has now been isolated from extracts of fresh brood wax using chromatography. Purification of the pheromone is monitored using a bioassay based on observing the response of individually caged queen bumble bees to paired glass fibre discs mounted onto plaster moulds resembling brood clumps. One disc from each pair is impregnated with a test fraction; the other serving as a control. Properties and structural information of the pheromone will be presented.

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STRUCTURE OF TWO BUMBLEBEE COMMUNITIES WITH PARTICULAR REFERENCE TO SIZE-VARIABILITY IN THE WORKER CASTE. Peter Söwig* & H.F. Paulus, Dep. Zoology; Albertstr. 21a; D-7800 Freiburg; FRG.

This paper deals with the question, how far size variability enables intraspecific sharing of resources and interspecific reduction of competition. In two regions (A: intense agriculturally used area with surrounding woods and waysides; 220 mNN; B: subalpine meadows; 2000 mNN) bumblebee workers were caught randomly and their wing-length was measured. In both regions 7 bumblebee species were frequent. Knowing the species specific regression-equation, proboscis-length can be computed from wing-length.

Success and time of flower visits can depend from both, proboscis-length and bodysize (measured as wing-length). Distributions of 7 species among these 2 ecomorphologically important parameters overlap in both regions less than expected from random distribution. In region B the average overlap was smaller than in region A. Although subalpine meadows are climatically more unstable than lowlands, mowing once a year is more predictable than irregular, man-made changes in small flower-patches on slopes, wood-edges and waysides in densely populated lowlands in Middle-Europe.

From the phylogenetical point of view it can be shown, that extreme long-tongued bumblebees are either primitive (Genus *Bombus*) or deviated (Subgen. *Megabombus* s.str.). Extremely short-tongued bumblebees belong to the deviated and probably monophyletic group of the "pollen-storers". They are able to rob nectar from deep flowers, and are more resistant against spatial-temporal heterogeneity.

#62

NOCTURNAL NESTING ACTIVITIES OF THE HORNET *VESPA CRABRO* (VESPIDAE, HYMENOPTERA): PRELIMINARY RESULTS OF INVESTIGATIONS BY MEANS OF AN INFRARED NIGHT VIEWING DEVICE. M.G. Walzl, Department of Anatomy, Institute of Zoology, University of Vienna, A-1090 Vienna, Austria.

In fall 1987 two nests (one built in a loft, one caged in a lab) were observed between 17:00 and 4:00 o'clock CET for a total of 43 hours. Observations distances to the nests (at first intact, then opened) varied between 50 cms and 2 ms. Measurements of temperature in one nest and surrounding it yielded a constant nest temperature between 28,5° and 29,5°C. Below 1 lux the nests are obviously not approached directly in flight but by walking. During darkness the nests were not guarded regularly but sometimes several workers inspected the outside of the envelope. Between 23:30 and 3:00 o'clock the hornets could be observed in a typical resting posture, with head and thorax inside the cell and abdomen sticking out. The resting state is characterized by a reduced frequency of abdominal ventilatory pumping and conspicuous convolutions of the tarsi. Contrary to queens and workers, males rest 1 hour at most. The resting periods are often interrupted for defecation of liquid excrements and to demand saliva droplets from the larvae. The excrements were spouted only from the lowest comb through the entrance hole. At dawn (4:00) the first workers left the nest.

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#63

MORPHOLOGIC FEATURES OF THE BACTERIAL MICROFLORA FROM THE INTESTINE OF *Apis mellifera* L. (HYMENOPTERA: APIDAE). C. Cruz-Landim, Biology Institute, UNESP, 13500 Rio Claro, SP, Brazil

Sections of different portions of worker honeybee guts were examined for microorganisms with transmission electron microscopy. The contents from the portions where their presence was confirmed were negatively contrasted with phosphotungstic acid and also examined with the electron microscope.

Presence of bacteria was verified in the mid and hind gut. All bacteria were bacilliform but the length of the rod was variable. The number of bacteria in the midgut is small. Only a few individuals were seen among the convolutions of the peritrophic membrane. In the hind gut they are numerous. In the small intestine the bacilli arrange perpendicular to the epithelium or remain randomly scattered in the lumen. In the rectum the number of bacteria scattered in the lumen is smaller. They generally cluster over the rectal pads. Some of them also stick perpendicular to the rectal epithelium. The bacilli present in the rectum seem to be longer than those present in the small intestine. These bacteria have a thin capsule and a tuft of pili in the pole toward the epithelia. Their protoplasm is dense except in the nucleoid zone and shows electron-dense granules. Bacteria with transverse septa are not uncommon.

#64

TAGGING AND MONITORING THE FORAGING POPULATION OF HONEY BEE (*APIS MELLIFERA* L.) COLONIES. R. A. Hoopingarner* and W. Boylan-Pett, Department of Entomology, Michigan State University, East Lansing, MI 48824-1115, U.S.A.

Mass marking of the total foraging population of honey bee colonies was accomplished using an entrance dispenser that dusted the thorax of each bee leaving the hive with fluorescent dye. Different dye colors were used for each colony or location. Foragers tagged on one day were marked for life. Their location within the hive and their number, relative to the total colony population, were documented by photographs taken at weekly intervals throughout a growing season. Dye marked bees were also tracked in field experiments.

#65

HORMONAL REGULATION OF BEHAVIORAL PLASTICITY IN HONEYBEE COLONIES G.E. Robinson¹, C. Strambi and A. Strambi². ¹Dept. of Entomology, Ohio State Univ., Columbus, OH 43210-1220, USA; ²CNRS, LNB 5, BP 71, 13402 Marseille, France.

Honeybee workers perform different tasks as they age (age polyethism). On the other hand, Juvenile Hormone (JH) titers increase with worker age and application of JH or JH analogs induces several effects on age-related behavior.

Despite the stereotyped pattern of behavioral development, workers are able to change their behavior according to naturally or experimentally induced abnormal colony needs. We considered, in the present study, two age-linked tasks: nursing (brood and queen care) performed by young bees and foraging, performed by older bees. One-day-old worker bees were provided with brood so that some young bees performed normally for their age and cared for the brood and queen while other young workers foraged precociously. As new bees were prevented from emerging, three weeks later there were overaged nurses and typical foragers. We measured JH titers in six groups:

- 7-day-old external control nurses. -21-day-old external control foragers.
- 7-day-old experimental nurses. -21-day-old overaged nurses.
- 7-day-old underaged foragers. -21-day-old experimental foragers.

We determined JH titers from 40 to 50 µl of hemolymph collected from groups of 10-15 workers, using the radioimmunoassay developed by Strambi et al. (1981). The results presented here show that despite their age:

- forager bees have always high JH titers
- nurse bees have always low JH titers.

These findings suggest that environmental variations act on JH titers to induce behavioral changes. Hormonally mediated behavioral plasticity of individual workers may account for colony resiliency in Honeybees.

Influence Of Improved Technology And Genetic Manipulation On The Potential Of Microbial Insecticides

THE BACILLUS THURINGIENSIS STORY: FLAGSHIP OF MICROBIAL CONTROL. C.C. Beegle, USDA,ARS,Insect Pathology Lab., Beltsville, MD 20705

B. thuringiensis was discovered by Ishiwata in 1901, described and named by Berliner in 1911, and reisolated by Mattes in 1927. The first field trials were conducted by Husz and Metalnikov about 60 years ago. The first commercial product, Sporeine, was produced in France in 1938. In 1957 the first U.S. B. thuringiensis product, Thuricide, was produced. Until 1970 the majority of products were based on isolates of the subspecies thuringiensis. Since 1970 the majority of products for use against lepidopterous larvae have been based on the subspecies kurstaki, discovered by Kurstak in 1962. Several million pounds of these products are annually produced with usage registered for nearly 30 crops and over 90 insect species worldwide. In 1976 Goldberg and Margalit found a new subspecies, israelensis, which is highly active against mosquito and blackfly larvae. At present both U.S. and European companies are producing and marketing israelensis based products, which have about 10% of the dipterous larvicide market. Presently there are intense efforts being made by numerous groups to develop novel ways to deliver the B. thuringiensis protein toxin. Examples are putting the responsible gene(s) into plant colonizing endophytes and epiphytes, and into the genomes of crop plants.

CRITICAL ROLE OF FORMULATION IN THE USE OF BACILLUS THURINGIENSIS FOR INSECT CONTROL. Terry L. Couch, Becker Microbial Products Inc., 9464 N.W. 11th Street, Plantation, Florida, USA 33322.

The mode of action of B. thuringiensis is primarily dependent on the proteinaceous delta-endotoxin produced during sporulation of the bacillus. The crystalline toxin and endospore are discreet, insoluble structures formulated as wettable powders, aqueous and non-aqueous liquids, dusts, granules and baits. The basic formulation is designed to maintain and preserve the toxicity and viability of the pathogen. Formulation additives also enhance efficacy by improving deposition characteristics and weathering properties. Factors affecting formulation strategies, additives and application systems will be reviewed.

A NEW ERA OF SYSTEMIC PESTICIDES GENETICALLY ENGINEERED IN PLANTS. M.J. Adang (Agrigenetics Advanced Science Co., Madison, WI) and A.N. Binns (University of Pennsylvania, Philadelphia, PA).

A continuing challenge in controlling pest insects is the development of plants resistant or tolerant to insect attack. One approach to accomplishing this objective is to express proteins that are deleterious to insects systemically in plants. Initial efforts have focused on the insecticidal crystal proteins of Bacillus thuringiensis. Different strains of this bacterium produce protein crystals during sporulation that are active against several orders of insects including, Lepidoptera, Diptera, and Coleoptera. Using appropriate vectors, genes encoding these insecticidal proteins have been delivered into plant cells, and in several cases, transgenic plants have been regenerated. The lepidopteran-active B. thuringiensis genes were the first to be engineered into plants. By selecting for expression of B. thuringiensis insecticidal proteins in such plants using ELISA and insect bioassays, insect-tolerant plants have been identified. Engineered tobacco and tomato plants have been produced that are resistant to feeding by tobacco hornworm larvae. Larvae ingesting leaves from these engineered plants stop feeding and die in several days. Work is also in progress to "introduce insect tolerance into additional crop species using the B. thuringiensis genes".

USE OF INSECT PATHOGENS TO SOLVE LOCALISED PEST PROBLEMS IN A COST EFFECTIVE MANNER. D.E. Pinnock, Department of Entomology, The University of Adelaide, Waite Agricultural Research Institute, South Australia 5064.

Insect pathogens are increasing in importance as control agents in agricultural pest management programmes, where their specificity permits suppression of certain pest species without undue interference with other biological control organisms. Although microbial pesticides are generally more costly than chemical pesticides, a consideration of the benefits of their use, especially where there are concerns about environmental or produce contamination, often reveals that their overall 'cost' is highly competitive. Also, recent advances in the genetic improvement of microbial control agents, and in the fermentation and formulation technology have further reduced the differences between the field performance of the microbial and chemical insecticides. These points will be illustrated by practical examples drawn from the use of Bacillus thuringiensis and Metarhizium anisopliae as microbial insecticides.

MICROBIAL CONTROL WITH NEMATODES: PATHOGENIC BACTERIA VECTORED TO THE TARGET INSECT. G.O. Poinar, Jr., Department of Entomology, University of California, Berkeley, California 94720.

Entomogenous nematodes of the genera Neoaplectana, Steinernema and Heterorhabditis carry and release pathogenic bacteria of the genus Xenorhabdus in the body cavity of insects. The infective stage juvenile nematodes protect and release the bacteria which create a suitable environment and provide a food source for the developing nematodes. This symbiotic relationship is relatively nonspecific and the combination have been used successfully against a wide range of insect pests throughout the world. There is no evidence that the nematodes or their bacteria can develop in warm-blooded vertebrates and they have been exempted from Federal regulation of the U.S. Environmental Protection Agency. Commercial companies marketing the nematodes for control of soil and plant dwelling insects are establishing unique delivery systems, desiccating nematodes for storage and shipping, conducting genetic manipulation and initiating production in large fermentation tanks. Incorporation of these techniques can lower the price and make these nematodes cost effective with chemical insecticides, thus permitting their use in numerous pest management programs.

A RE-EVALUATION OF THE USE OF FUNGI FOR INSECT PEST MANAGEMENT IN LIGHT OF NEW TECHNOLOGY. D.F. Perry*, Centre de foresterie des Laurentides, C.P. 3800, Ste-Foy, QC, Canada, G1V 4C7, and M. Arella, Institut Armand-Frappier, 531 boul. des Prairies, Laval, QC, Canada, H7W 4V9.

New technologies have recently enhanced our capacity to study fungal populations, to select and manipulate high performance strains and to establish detailed patterns for the interpretation of ecological phenomena. These techniques, adapted from baculovirus research are currently centered around DNA extraction, restriction fragment digestion and molecular hybridization. These methodologies are being adapted to three major pathogens of the eastern spruce budworm: Entomophaga aulicae, Erynia radicans and Paecilomyces farinosus. Improved detection, diagnostic and epidemiological capabilities results are leading to better population analyses with renewed hope for the selection and subsequent manipulation of fungal entomopathogens.

Influence Of Improved Technology And Genetic Manipulation On The Potential Of Microbial Insecticides

IDENTIFICATION OF DETERMINANTS REGULATING THE PATHOGENICITY OF ENTOMOGENOUS FUNGI. D.G. Boucias*, J.C. Pendland, Department of Entomology & Nematology, University of Florida, Gainesville, Florida 32611 USA.

The potential for utilizing genetic methods to engineer improved strains of entomopathogenic fungi has stimulated renewed interest in this group of pathogens. At present, the technology, transformation methods, shuttle vector systems, etc. has been developed for industrially important fungal and yeast systems and could be readily adapted for redesigning insect mycopathogens. Fundamental to the success of this approach is the identification of determinants regulating the virulence of these fungi to host insect systems. Over the past years our laboratory has researched the dimorphic mycopathogen *Nomuraea rileyi* with emphasis to its *in vivo* growth in host lepidopteran systems. Our studies have revealed that successful infection depends upon a sequential production of developmental stages. The penetration through the host cuticle is one of the unique attributes of entomogenous fungi and has been subject recently to extensive investigation. This process mediated by exocellular enzymatic activities is one stage which is highly suitable for biochemical analysis and as such will be reviewed in detail. Secondly the dimorphic capability, ability to convert from germ tube-yeast-mycelium is considered to be paramount for the genus to evade the host immune system.

GENETIC MANIPULATION OF BACULOVIRUSES AND ITS POTENTIAL FOR INSECT PEST CONTROL. J.M. Vlak. Department of Virology, Agricultural University, P.O. Box 8045, 6700 EM Wageningen, The Netherlands.

Baculoviruses are insect pathogens with potential as biological control agents as alternative to chemical insecticides. They have a limited host-range and do not occur outside the arthropod kingdom. In addition, they are stable in the environment and can persist for many years in the ecosystem. There are, however, a few limitations to a widespread use of these viruses. They are UV sensitive and have a relatively low 'speed of kill'. In addition, baculoviruses have a host-range which is too limited to be commercially attractive. The employment of genetic engineering techniques may be helpful to overcome some of these limitations.

The most attractive venue in the short run is the engineering of recombinants with increased virulence and/or 'speed of kill'. This may be achieved by the engineering of genes coding for toxic or disruptive substances, such as endotoxins, neuropeptides or enzymes under the control of viral promoters. In the long run, recombinants with extended host-range may be engineered as soon as the genes determining host specificity are identified. Recently, it has been found that the engineering of specific deletions in wild-type baculoviruses also resulted in viruses with increased virulence.

COMMERCIAL CONSIDERATIONS IN THE DEVELOPMENT OF CODLING MOTH GRANULOSIS VIRUS. M.G. RICHARDS*¹ and J. Ballard² 1. Agricultural Genetics Company Ltd, Cambridge Science Park, Cambridge CB4 4GG, U.K. 2. Institute of Horticultural Research, Littlehampton, W. Sussex BN17 6LP, U.K.

The codling moth, *Cydia pomonella* (L.) is a key pest of apples, pears and walnuts in most temperate regions of the world, requiring regular spraying to prevent up to 100% crop loss. The use of broad-spectrum chemical insecticides for codling moth control stimulates secondary insect and mite pest outbreaks requiring further control intervention. Since 1963, trials carried out in Europe, North America and Australia with a naturally occurring granulosis virus (CpGV) of the codling moth have shown effective and selective control of codling moth, while allowing a reduction in secondary pest problems. AGC is funding research at the AFRC Institute of Horticultural Research on the development of a commercial product based on CpGV.

The suitability of this agent to commercialisation with respect to production, field efficacy, registration and marketing is discussed and contrasted with chemical insecticides.

AN ECOLOGICAL APPROACH TO THE EFFECTIVE USE OF VIRAL INSECTICIDES. P.F. Entwistle, Natural Environment Research Council, Institute of Virology, Oxford OX1 3SR, UK.

Being 'living' organisms with special environmental requirements for efficient action, the optimal use strategy for viruses will inevitably be more complex than for chemical insecticides. It is therefore essential to develop a conceptual model to guide decision making in the manipulation of any particular insect-virus associated for maximum economic benefit. A model is offered in which the feasible use strategies of an insect virus are derived from a knowledge of the nature of its adaptation to hosts in various zones of the r-K continuum in the synoptic model of Southwood & Comins (*J. Anim. Ecol.*, 45, 949).

At present spraying is the dominant methodology of delivering baculoviruses to larval Lepidoptera and sawflies. The parameters of successful spraying can be derived from a knowledge of host susceptibility to infection (determines dose), feeding activity (determines droplet density on crop) and feeding site (defines spray droplet target). Feeding site may also influence the selection of droplet size, crop penetration by sprays increasing with increasing drop size. The limits of u.v. protection technology are determined by drop size whilst droplet position on the crop (degree of exposure) determines its necessity.

ASSESSING THE RISK OF RELEASING GENETICALLY MODIFIED INSECT PATHOGENS. J. Huber, Biologische Bundesanstalt, Darmstadt, Germany F.R.

The advances recombinant DNA technology made in the last few years, offer exiting opportunities to improve some traits of insect pathogens with regard to their performance in pest control. It has been suggested to apply this novel technique to (a) change the host range, (b) enhance virulence, (c) improve persistence, or (d) shorten the lethal time of these pathogens. Since the genetically modified microorganisms and viruses are meant for deliberate release into the environment, their safety has to be ascertained. The potential hazards foreseen with genetically engineered pathogens are, for most part, the same as for non-engineered microbes. The dissemination of such an 'artificial' pathogen resembles in most aspects the introduction of a naturally occurring germ into a new environment, e.g., by transferring it from one continent to another. Therefore, the assessment of risk involved in the release of a new microorganism or virus should be based mainly on the nature of the pathogen and the environment into which it is going to be disseminated and not so much on the way by which it was obtained.

A major concern is the potential risk of genetic transfer and exchange of engineered traits with naturally occurring microorganisms or with host or non-host macroorganisms, thereby creating new potential hazards. One of the first tasks in risk assessment should therefore be the detection and measurement of this potential transfer, using a full range of experimental protocols, from test-tubes, over contained model-ecosystems, up to field trials.

CAN BACULOVIRUSES COMPETE WITH *BACILLUS THURINGIENSIS* AS MICROBIAL INSECTICIDES? J.C. Cunningham, Forest Pest Management Institute, Canadian Forestry Service, P.O. Box 490, Sault Ste. Marie, Ontario, Canada P6A 5M7

Bacillus thuringiensis (B.t.) is the only microbial insecticide which has been successfully commercialized, with annual sales of about \$35 to \$45 million. Worldwide, B.t. is registered for control of about 50 Lepidopterous pests, but the bulk of sales is to the North American forestry market. Compared to B.t., baculoviruses have a very narrow host range, take longer to kill the target pest and usually cost considerably more to produce. Viruses are grown in insect host larvae, whereas B.t. is produced by deep tank fermentation. Some viruses can initiate epizootics which does not occur with B.t.; vertical and horizontal transission of viruses can occur in undisturbed environments such as forests, plantations and pastures. There are currently about 14 viral insecticides registered worldwide with at least 5 of these registrations held by government agencies. The future use of baculoviruses will probably be in forestry and plantations where they fulfil specialized requirements and in developing countries where they can be produced for agricultural use as a cottage industry. Genetic engineering techniques are being applied to both B.t. and baculoviruses. Commercial interest in B.t. is targeted on improved microbial insecticides, whereas commercial interest in baculoviruses is mainly for production of pharmaceuticals and vaccines.

DO LATENT BACULOVIRUSES EXIST AND WHAT IS THEIR IMPORTANCE? H.A. Wood*, I.R.L. Smith and N.E. Crook, Boyce Thompson Institute at Cornell, Ithaca, NY 14853, USA and AFRC Institute of Horticultural Research, Littlehampton, West Sussex BN17 6LP, UK.

In nature, spontaneous baculovirus epizootics characteristically occur in insect populations which reach a high density. It has long been suspected that these viral epizootics may arise by the induction of productive virus replication in latently infected insects. We have obtained indirect evidence for the existence of a latent granulosis virus (GV) in *Pieris brassicae* and a latent nuclear polyhedrosis virus (NPV) in *Lymantria dispar*. Firstly, we have shown that the *L. dispar* NPV can be transovarially transmitted. This is a prerequisite event for maintenance of persistently infected insect populations. Secondly, we have induced productive replication of the *P. brassicae* and *L. dispar* baculoviruses in "healthy" larvae. The inducers were baculoviruses which are incapable of replicating in each host. The induced virus was characterized by DNA restriction endonuclease fragment profiles. We are conducting stringent experiments designed to eliminate all possibility of adventitious contamination, and to evaluate the physical state and distribution of the viral genome in persistently infected insects.

THE GENETICS OF RESISTANCE OF THE INDIAN MEAL MOTH *PLODIA INTERPUNCTELLA* (HÜBNER) TO A GRANULOSIS VIRUS. F.R. Hunter-Fujita* and K. Vigneswaren, Department of Microbiology, The University of Reading, London Road, Reading, Berkshire, RG1 5AQ, U.K.

Two strains of *Plodia interpunctella* one designated 'resistant' and the other 'susceptible' were identified that differed in their susceptibility to a granulosis virus. Larvae of the 'resistant' strain required approximately 1000 times more virus than those of the 'susceptible' strain for an LD₅₀ value when exposed to virus during the late third or early fourth instar. During middle second instar, however, the 'resistant' strain was significantly more susceptible to virus than the 'susceptible' strain.

To determine the mode of inheritance of resistance to infection with virus, reciprocal crosses were made between the 'resistant' and 'susceptible' strains and the F₁ progeny that resulted were backcrossed with the parental strains. F₂ generations of the two reciprocal crosses were also established. It appeared from the responses to virus recorded for the F₁ and F₂ reciprocal crosses and the F₁ backcrosses that resistance was under polygenic control involving autosomal factors exhibiting partial dominance.

POPULATION ASPECTS OF RESISTANCE TO NUCLEAR POLYHEDROSIS BY *SPODOPTERA FRUGIPERDA*. James R. Fuxa, Department of Entomology, Louisiana State University, Baton Rouge, Louisiana 70803 USA.

Observed patterns of disease prevalence in the field led to a series of studies of resistance by fall armyworm (*Sf*, *Spodoptera frugiperda*) to its nuclear polyhedrosis virus (NPV). Median lethal doses (LD₅₀s) of NPV in populations of *Sf* sampled throughout the western hemisphere were similar to the LD₅₀s in a laboratory colony selected for resistance to NPV. There were no consistent patterns of LD₅₀s over time in Louisiana, but the heterogeneity of the data increased as each season progressed. Cluster analyses of the geographical data indicated that *Sf* from the northern hemisphere could be distinguished from a population in Brazil based on patterns of susceptibility to viral isolates. The resistant laboratory colony regained susceptibility to NPV within 3 generations after selection pressure was removed. The resistant *Sf* were cross-resistant to granulosis virus and to *Autographa* NPV, but they were significantly more susceptible to the insecticide methyl parathion than the NPV-susceptible *Sf* were. The NPV-resistant and susceptible insects were equally susceptible when the NPV was injected directly into the haemocoel or when methyl parathion was applied topically rather than fed to the insects.

EVOLUTION AND COEVOLUTION IN INSECTS AND INSECT VIRUSES. S. Lindfield* and M. Begon, Department of Zoology, University of Liverpool, P.O. Box 147, Liverpool L69 3BX, U.K.

One of the several disadvantages of chemical insecticides is the prodigious ability of pests to develop resistance against them. With viruses (and other biologicals), there is much less evidence of insects evolving resistance or anything similar, and the possibility exists that the virus would counter any evolutionary change in the pest with a co-evolutionary response of its own.

Here, we first review the theoretical literature on the coevolution of hosts and parasites, and we discuss, in particular, the light that this throws on interactions between insects and insect viruses. Then we describe our own work on possible co-evolutionary interactions between *Plodia interpunctella* (the Indian meal moth) and its granulosis virus (GV). Moth stocks subjected to high doses of GV over a number of generations have been examined for evolutionary changes in resistance and general vigour; while GV strains passaged through moths at very low doses for a number of generations have been examined both for phenotypic (virulence) and genotypic evolutionary change. Our results are then compared with those from related studies.

DYNAMICS OF THE HOST:VIRUS INTERACTION ASSESSED BY IN VIVO BIOASSAY. P.R. Hughes* and N.A.M. van Beek, Boyce Thompson Institute for Plant Research, Cornell University, Ithaca, New York, USA 14853.

The evolutionary and ecological consequences of specific characteristics of baculoviruses are of considerable interest. Techniques have been developed to permit assessment of the ramifications of many of these properties by in vivo bioassay. An exponential model and a birth-death model have been used with these techniques to evaluate various aspects of the virus:host relation including the proportion of virus effective in initiating infection, the in vivo rate of virus increase under given conditions, the relation between number of nucleocapsids per virion and larval survival time, the proportion of nucleocapsids in a virion contributing to virus replication, and the relation between temperature and rate of virus increase. The techniques and models will be described and examples given of their application.

ENVIRONMENTAL INFLUENCES ON VIRUS TRANSMISSION AND INSECT SUSCEPTIBILITY. Leif Øgaard, Dep. of Zoology, Royal Veterinary and Agricultural University, Bülowsvej 13, 1870 Fr.B.C., Copenhagen, Denmark.

In mathematic models - describing the development of disease in insect populations - transmission coefficients, mortality rates and density of host and pathogen play a major role for the predicted host-pathogen relationship.

The transmission coefficients are not easily defined and probably affected by many environmental factors. The environment - or sudden changes in the environment - may affect the response of host specimens to any inoculum of a pathogen. This could happen due to altered susceptibility because of stress or the presence of other pathogens.

Additionally, the environment may influence the amount of pathogens received. This could be the spread of pathogen by weather factors, altered behaviour of the hosts, and altered virulence/activity of the pathogen. Similarly, a higher output of pathogen in the habitat - due to proliferation of a pathogen in other host species - may influence the number of insects becoming infected.

Attempts will be made to describe the influence of environmental factors on the transmission coefficients in a host-pathogen model. Results from investigations on the transmission of *Granulosis virus* in danish populations of cutworms (*Turnip moth*, *Agrotis segetum*) and on the effect of stress on susceptibility of french (*G.Biache*, INRA, La Miniere) and danish populations of the cutworms will be presented.

INTERACTION BETWEEN VIRUSES, PARASITES, AND PREDATORS OF INSECT PESTS. M.S.T. Abbas, Plant Protection Research Institute, Nady El-Said Street, Dokki, Giza, Egypt.

Insect viruses are considered the most promising biocontrol agents to be used against insect pests as microbial insecticides. The importance of insect viruses, mainly baculoviruses, attributes to their high virulence as well as their specificity. The interactions among virus, host, parasites and predators have been investigated by many workers. Our studies revealed that NPV of *Anticarsia gemmatilis* had no detrimental effect on the predators, *Calleida decora*, *Tropiconabis capsiformis* and *Geocoris punctipes*. Also, NPV of *Spodoptera littoralis* did not adversely affect the predators, *Orius albidipennis*, *Chrysopa carnea* and *Labdura riparia*. All predators, fed on virus-infected preys, were found to excrete detectable amounts of polyhedral inclusion bodies (PIB) virulent to healthy larvae. The ecto-larval parasite, *Bracon brevicornis* developed successfully when its host, *Heliothis armigera* was parasitized 24 h after virus-infection. Only 24.6% of the parasite's progeny developed to adults when parasitization occurred 48 h post-infection. However, all parasite's progeny died in the egg and larval stages when parasitization occurred 3, 4, 5 or 6 days post infection.

ECOLOGICAL CONSIDERATIONS AND RESEARCH RAMIFICATIONS OF RELEASING GENETICALLY MANIPULATED INSECT VIRUSES. J.S. Cory and P.F. Entwistle, Natural Environment Research Council, Institute of Virology, Mansfield Road, Oxford OX1 3SR, UK.

Control using baculoviruses (BVs) is slower than other methods due to an unavoidable period of disease incubation. This may result in crop damage. The incorporation of foreign genes into a BV may reduce the interval between infection and death and minimise crop damage. Before field release of such a genetically modified BV any associated risks must be carefully assessed. This must be based on a thorough ecological understanding of the BV in nature. We are currently involved in a programme to evaluate the ecology and release risks of a BV genetically labelled by insertion of an unique non-coding DNA sequence to allow identification. The environmental consequences in key areas such as host range, genomic recombination, persistence and dispersal, are being assessed initially under strict containment conditions.

The possible ecological consequences of the use of significantly modified BVs (increasing BV lethality and/or reduced environmental stability) are discussed in the context of current understanding of BV-host population dynamics in both forest and agricultural ecosystems.

DISEASE AND POPULATION CYCLES OF FOREST LEPIDOPTERA. J.H. Myers, The Ecology Group, Depts. Zoology and Plant Science, Univ. British Columbia, Vancouver, Canada.

Viral disease, is one of many mortality agents of forest Lepidoptera at high density, but is rarely thought to explain cyclic declines. However, disease may explain several features of population cycles: (1) reduced fecundity following the decline, (2) synchronous decline of populations with different histories (3) behavioral variation of individuals in different phases of population change, and (4) mortality of late instars in the first year of the decline and of early instars in subsequent years. Major questions remain about disease in insect population cycles: (1) Is the epidemiology of disease totally density-dependent or can disease be carried in an innate and inactive form? (2) Does mortality from disease select for resistant individuals and therefore cause a major shift in the "quality" of the population over the fluctuation? (3) Do sublethal effects of disease reduce the vigor and fecundity of insects and therefore prolong the decline for several generations? Cyclic population dynamics arise from processes that have negative effects on the rate of population increase and act in a delayed, density-dependent manner. Disease could fit these criteria and be responsible for population cycles of forest Lepidoptera

MODELLING THE SPREAD AND IMPACT OF INSECT VIRUSES. W. van der Werf and R. Rabbinge, Department of Theoretical Production Ecology, Agricultural University, P.O.B. 430, 6700 AK Wageningen, the Netherlands.

An insect population, its plant host and a viral pathogen constitute a complex system with interrelations at several levels of organization. The systems behaviour at each level results from the integration of sub-level processes.

Mathematical models are a tool to analyse system behaviour. Two broad categories of models can be distinguished: (1) one-level, descriptive models and (2) multi-level, explanatory models. A wide range of descriptive models exists, e.g. the analytical Lotka-Volterra models of pathogen-host population dynamics and regression models. In these models, the environment is generally neglected or treated in a static manner, i.e. not depending on time. The system is modelled with one or a few relations between independent and dependent variables from the same integration level. Most models in epizootiology are of this type. Although they are useful for the analysis of systems in a broad sense and help to gain insight, their potential as management tools is limited because they are too simplified in their basic assumptions.

Dynamic, explanatory models interpret the system on the basis of elaborate quantitative knowledge of relations with the environment and basic processes at lower integration levels. The life cycle of the insect host, propagation and dispersal of the virus, its inactivation and transmission mode, the dose-response relationship and the incubation period are included in these models. In this way they bridge the gap between laboratory and field experiments. Construction of these models and comparison of their behaviour to that of real systems provides insight and understanding. Explanatory models are rare in epizootiology, probably because of the many basic relations that must be quantified. Some examples of explanatory models will be discussed in our contribution to this congress.

PHAGOCYTIC RECOGNITION IN *BOMBYX MORI*. H.Wago, Department of Bacteriology, Saitama Medical School, Moroyama, Iruma, Saitama 350-04, Japan.

In *B.mori*, the granular cells play key roles as a phagocyte to eliminate foreign materials invading into the hemocoel, and the elongation of filopodia present on the cell surface is important in the expression of phagocyte function. A series of experiments have showed that (a) a filopodial elongation is related to nonself recognition, (b) microfilaments are involved in filopodial function, and (c) a certain level of intracellular phagocytic signal obtained during elongation is required for evoking the phagocyte behaviour. Moreover, recent works suggested that rapid attachment of cells completely depended on the presence of phenol-oxidase (PO) in the plasma and that once-attached cells formed melanin from substrate by trapping proPO in the coagulum produced on the cell surface after degranulation, thus PO serving as opsonin. Then, lectin-receptors are induced on only the granular cells simultaneously with the appearance of lectin activity in relation to pupation. Therefore, this specific recognition system is also essential in the elimination of lectin-binding foreignness as well as disintegrated self-components produced on pupation. As foreign materials except for allograft or injured sites of allograft are treated as nonself by the granular cells irrespective of absence or presence of PO or lectin, they seem to be able to recognize allograft as a self component.

PHAGOCYTOSIS OF DIFFERENT BIOLOGICAL PARTICLES BY THE PLASMATOCYTE (IMMUNOCYTE) OF *Penstrongylus megistus* (HEMIPTERA: REDUVIIDAE). M. A. Barracco* and C. T. Loch, Department of Biology, Federal University of Santa Catarina, P. O. Box 476, 88.049 Florianopolis-SC, Brazil.

Five hemocyte types were found in the hemolymph of *P. megistus*: prohemocytes, plasmatocytes, granulocytes, oenocytoids, and adipohemocytes. Only the plasmatocytes (PLs) were able to phagocytize different biological particles, such as chicken erythrocytes and the protozoan, *Trypanosoma cruzi* introduced artificially into the hemocoel, and bacteria and viruses from natural contamination. All the foreign particles seemed to be internalized inside membranous vacuoles. Endocytized bacteria and chicken erythrocytes were observed in different stages of degradation, probably owing to lysosomal enzyme activity. PLs, however, were not considerably affected even when large numbers of ingested bacteria were present. Natural contamination with viruses seemed to cause a clear cell degeneration, and several myelin figures were observed surrounding the vacuoles containing the viral particles. In the case of *T. cruzi*, phagocytosis by the PLs was clearly observed. The parasites, however, were not digested and multiplied significantly inside the immunocytes.

IMMUNE REACTION OF *BLATTELLA GERMANICA* (L.) (DIPTERA:BLATTELLIDAE) IMMUNOCYTE (GRANULOCYTE) TO FOREIGN IMPLANTS. S.S. Han* and A.P. Gupta, Department of Entomology, Rutgers University, New Brunswick, NJ 08903, USA.

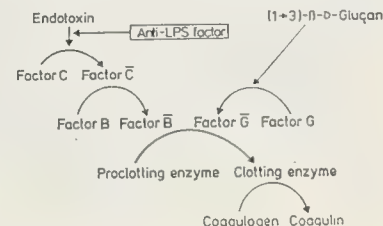
The granulocyte (GR) is discoid and contains marginal microtubule bundle in its plane of flattening. Following implantation of a foreign tissue (xenogeneic nerve cord and surgical suture), the GRs become activated and show considerable increase in the number of both the microtubules and the nuclear pores of the nuclear envelope. The large number of microtubules is necessary to maintain the flattened nature of the GRs against the deforming and shearing forces of the foreign tissue. The concomitant increase in the number of nuclear pores indicates high turnover of the tubulin pool in the GR cytoplasm, necessary for the rapid assembly of the microtubules in the encapsulating GRs. The latter also form desmosome-like, intermediate-, B-type gap-, and pleated septate junctions among them, the latter type demonstrated for the first time by both thin section and freeze-fracture methods. The encapsulating GRs constitute a separate subpopulation of immunocytes and differentiate in the hemopoietic tissue (part of the dorsal diaphragm near the heart) located between the abdominal segments 1-4.

COMPUTER IMAGING OF ARTHROPOD IMMUNOCYTES. S.M. Dunn* and A.P. Gupta, Department of Electrical Engineering and Department of Entomology, Rutgers University, New Brunswick, NJ 08903 USA.

Although the major arthropod hemocytes can generally be identified by various methods, the results are not free from random errors of identification. In addition, there are long-standing controversies regarding such hemocytes as coagulocytes, the so-called crystal cells, adipohemocytes, and other hemocyte types that exist in the literature. We have used computer imaging to resolve some of the above controversies. Light, scanning, and transmission electron micrographs of immunocytes and other hemocyte types were digitized and processed, using classical image processing methods to determine a robust set of image features that will be used to automatically classify hemocyte images from any of the 3 image modalities. The features describe the cell size and shape, external boundary continuity, and organelles. In addition, we are able to display 3 dimensional reconstructions of hemocytes from serial sections of each imaging modality. Our overall goal is to provide a computer-assisted system for reliably identifying immunocytes and other hemocyte types, and a means for visualizing immunocytes in 3 dimensions.

MOLECULAR MECHANISM OF HEMOLYMPH COAGULATION CASCADE IN *LIMULUS*. S. Iwanaga*, T. Miyata, T. Nakamura, F. Tokunaga and T. Muta, Department of Biology, Faculty of Science, Kyushu University 33, Fukuoka 812, Japan.

The hemocytes circulating in *limulus* hemolymph contain a clotting system, which participates both in hemostasis and in defence against invading microorganisms. Our biochemical studies on this system indicate that the hemocytes contain several serine protease zymogens, which constitute a coagulation cascade triggered by endotoxins and (1→3)-B-D-glucan. Up to now, six protein components, designated coagulogen, proclotting enzyme, factor B, factor C, factor G and anti-LPS factor, all of which are closely associated with the coagulation pathway, were purified and biochemically characterized. Among these components, the covalent structures of coagulogens isolated from four species of *limulus* were established. Moreover, the cDNA cloning and whole nucleotide sequence for the zymogen factor C are being studied. We will discuss here a mechanism of the *limulus* coagulation cascade shown in figure.



ANTIBACTERIAL IMMUNITY IN LEPIDOPTERA. J.S. Chadwick, Department of Microbiology and Immunology, Queen's University, Kingston, Ontario, Canada K7L 3N6

Antibacterial activity in Lepidoptera is complex involving both cellular and humoral components of hemolymph. A few bacterial species are pathogenic for Lepidopterous insects and demonstrable antibacterial activity may be shown after immunity is induced via introduction of avirulent or attenuated bacteria or their products. We found that Cane Sugar Factor, presumably a non-bacterial product, will induce comparable protective immunity against Gram-negative bacteria in *Galleria mellonella*. Swedish investigators showed mainly in *Cecropia* moths that basic proteins referred to as cecropins or attacins, are probably responsible for most antibacterial immunity. In *G. mellonella*, although antibacterial substances occur in cell-free hemolymph, hemocytes are triggered by bacteria or lipopolysaccharide to induce the fat body to generate the antibacterial proteins. Ultrastructural damage first occurs at the target cell membrane and proceeds rapidly to cell lysis. In the model insect, *G. mellonella*, the vaccines of all Gram negative bacteria induce similar protein profiles in hemolymph, but against certain bacteria no protective immunity is achieved. *Serratia marcescens*, for example, produces proteases which, *in vitro* destroy the newly synthesized proteins. However immunity cannot be achieved against protease-free mutants, suggesting a complexity in relation to recognition, virulence factors and scope of activity of induced proteins.

ANTIBACTERIAL PROTEINS IN INSECTS OTHER THAN LEPIDOPTERA AND DIPTERA. P. Götz, M. Riemer, G. Reinicke and T. Trenczek, Institute for General Zoology, Free University of Berlin, D-1000 Berlin (West) 33.

In some insects injection of bacteria into the hemocoel causes an increase in lysozyme concentration and neosynthesis of inducible antibacterial proteins (IAP). This is especially known from diptera and from lepidoptera where successful biochemical analysis of IAP (cecropins and attacins) was first performed by Boman and coworkers in Sweden. Antibacterial activity from other insects has also long been known, e.g. from Heteroptera and Saltatoria, but its chemical nature - except for lysozyme - remained unclear.

Choosing insects from different systematic groups (Odonata, Phasmida, Blattodea, Saltatoria, Heteroptera, Coleoptera and Hymenoptera) we injected different doses of log phase *Enterobacter cloacae*. IAP could be demonstrated in certain species of Heteroptera, Coleoptera and Hymenoptera. Polyacrylamide gel electrophoresis was used to characterize the chemical nature and molecular weight of the IAP.

IAP of these different insects was tested for susceptibility to an immune inhibitor from the entomopathogenic nematode *Neoaplectana carpocapsae*.

IAP were found in all lepidopteran and dipteran species so far investigated. In other insect groups, especially among hemimetabolic insects, the occurrence of IAP is scattered, and even closely related species may differ in their capacity of producing antibacterial proteins. Therefore, the immune system of insects with and without IAP was compared in regard to bacterial clearance, encapsulation and phenoloxidase activity.

BACTERIAL CHALLENGE AND SIGNIFICANCE OF INDUCIBLE PROTEIN IN WOUND-HEALING IN *MANDUCA SEXTA*. K. D. Spence* and M. F. Minnick, Department of Microbiology, Washington State University, Pullman, WA 99164-4340.

A bacteria-induced protein, termed M13 ($M_r \approx 70K$), has been purified from the hemolymph of immunized *Manduca sexta* larvae. M13 is an apparently bifunctional protein possessing both a glucose-lectin activity and a non-lectin (coagulating) activity; its addition to non-immune hemolymph triggers immediate hemocyte coagulation. M13-mediated hemocyte coagulation and erythrocyte agglutination may be inhibited with either glucose or anti-M13 antibody. The injection of anti-M13 antibody into fifth instar larvae blocks their ability to seal even needle wounds, and the animals effectively bleed to death. Immunological screening of naive and immune larval tissues by immunoblot techniques with anti-M13 antiserum suggests that the epidermis is the source of hemolymph M13. A smaller, antigenically crossreactive protein termed M13-CRP ($M_r \approx 33K$) has also been detected in the epidermis. M13-CRP appears to be a hydrolytic product of M13. Similar crossreactive proteins have been detected in the epidermis (but not the hemolymph) of wandering larvae, prepupae and pupae.

LIMULUS C-REACTIVE PROTEINS: PROTEIN STRUCTURE, GENOMIC STRUCTURE, AND POSSIBLE FUNCTION. T.-Y. Liu* and N.Y. Nguyen, Division of Biochemistry and Biophysics, CBER, FDA, 8800 Rockville Pike, Bethesda, MD 20892, U.S.A.

The protein structures and the genomic structures of three homologous *Limulus* C-reactive proteins (CRPs) have been determined and compared to that of the human, and rabbit. In the human CRP gene there is an intron separating the signal peptide and the coding region. In *Limulus* this intervening sequence is missing. The *Drosophila* heat shock consensus sequence found in the genes of human and rabbit CRP at the 5' end, is not found in the *Limulus* CRP genes. Whereas a single CRP gene was found in human, multiple genes were found for the *Limulus* CRPs. All CRPs exhibit calcium-dependent phosphorylcholine ligand binding properties. The coding regions of the *Limulus* and human CRP gene share approximately 25% identity and two stretches of highly conserved regions, one of which falls in the proposed phosphorylcholine binding site, while the other site is very similar to the consensus sequence required for calcium binding in calmodulin and related proteins. The structural and functional studies provide convincing evidence to support the evolutionary relatedness of the human and *Limulus* CRPs.

PRODUCTION AND FORMULATION OF ENTOMOPATHOGENIC VIRUSES FOR PEST CONTROL IN DEVELOPING COUNTRIES. K.A. Jones*, D.J. McKinley, D. Grzywacz and G. Moawad†, Overseas Development Natural Resources Institute, Porton Down, Salisbury, Wiltshire SP4 0JQ, UK †Plant Protection Research Institute, Dokki, Cairo, Egypt.

Insect viruses provide a safe, non-toxic method of pest control suitable for use in developing countries. They can be produced and formulated locally saving valuable foreign exchange which would otherwise be spent on importing chemical insecticides. In Egypt we have developed a production method in which virus infected insects are individually reared in aluminium honeycombs, harvested prior to death and incubated at low temperature to maximise virus yield. This results in low bacterial contamination; eliminating the need to carry out expensive purification procedures. Next the insects are freeze dried and ground with a number of additives to produce a wettable powder. Tests have shown that the insect debris affords considerable protection to the virus and only a bulking agent, a physical screen against UV, a dispersant and a sticker are necessary.

VERS UN MÉTHODE DE LUTTE INTÉGRÉE CONTRE *EPICERURA PERGRISEA* HAMPSON (LÉPIDOPTÈRE: NOTODONTIDAE), LE DÉFOLIATEUR DES *TERMINALIA* SP. EN CÔTE D'IVOIRE. L. Kanga*, G. Fediere² et D. Dauthuille^{2, (1)} CTFT, 08 B.P. 33, Abidjan 08, Côte d'Ivoire; ⁽²⁾ ORSTOM, B.P. V-51, Abidjan, Côte d'Ivoire.

Epicerura pergrisea Hampson est le principal défoliateur du *Terminalia superba* Engl. et Diels et du *Terminalia ivorensis* A. Chev. en Côte d'Ivoire. La persistance et l'intensité des attaques qui entraînent une perte de productivité de 3 m³/ha/an en volume bois fort du peuplement, a motivé à court terme l'utilisation de pesticides (Deltaméthrine, Evisect, Diflubenzuron, *Bacillus thuringiensis* ..). Le développement d'une épizootie dont l'agent causal est un virus icosahédrique de 30nm de diamètre, possédant un caractère hautement pathogène (infection per os) fonde des espoirs sur son utilisation en lutte biologique combinée.

STUDIES ON FIVE NEW ENTOMOPOXVIRUS ISOLATES FROM GRASS-HOPPERS AND LOCUSTS, AND THEIR POSSIBLE USE IN BIOLOGICAL CONTROL. K. Purrini, Yemen-German Plant Protection Project, Sana'a, P.O. Box 26, Yemen Arab Republic.

It is recognized that grasshoppers and locusts with their high biological potential are the most devastating crop pests in the world. There are little data available on pathogens of these insect groups. Our research work fill this gap. During investigations period 1983-1987 in Tanzania and Yemen, A.R., among other pathogens (12 new microsporidians and many parasitic protozoa) 5 new entomopoxvirus isolates were found to be associated with the natural populations of *Locusta migratoria*, *Schistocerca gregaria*, *Zonocerus elegans* and other Orthopteran hosts. Because of the significance of grasshoppers and locusts as crop pests throughout the world, our investigations are concentrated on the level of infectivity of viruses for different Orthopteran hosts. The laboratory experiments on a possible occurrence of beneficial interactions between entomopoxvirus-isolates following dual, triple or multiple infections are underway. The results of the light and electron microscope examinations are discussed.

INVESTIGATION OF DIFFERENT FACTORS FOR DETECTION OF NUCLEAR POLYHEDROSIS VIRUS BY MOLECULAR PROBES. M. Nadeau*¹, D. Perry², A. Verbeek¹, S. Bellonck¹, P. Tijssen¹ and M. Arellal¹, ¹ Virology Center, Institut Armand-Frappier, Laval, Quebec, Canada H7W 4V9. ² Centre de Recherches Forestières des Laurentides, Ste-Foy, Quebec, Canada H7N 4Z3.

Baculoviruses are important pathogens for different insects and are considered or utilised as biological control agents. Specific and sensitive detection tools are of major importance for both research purposes and pest management. Here, probes obtained by cloning of *Choristoneura fumiferana* nuclear polyhedrosis virus (CNPV) genomic fragments, are examined as detection tools by means of solid support hybridization (hybridot assay). Effects of different fixation- and hybridization conditions on the detection signal are described.

The nature and concentration of the denaturing agents as well as temperature, during treatment of the viral sample, were shown to have important impact on detection signal. During hybridization, the presence of dextran sulfate increased the signal, while formamide concentration influenced the specificity of the probes. Also, probes labeled by random-primer extension gave a stronger signal than those marked by nick-translation. The probes appeared to be CNPV-specific when tried against CfcGV, BmNPV, and LdNPV, as no detection was obtained when hybridization was carried out at 42°C and 50 % formamide.

These data provide a good basis for further developement of a rapid, sensitive and specific detection assay for NPV in *C. fumiferana*.

THE ROLE OF VIRUS-LIKE PARTICLES IN A PARASITOID-HOST RELATIONSHIP OF INSECTS

O. Schmidt* and I. Schuchmann-Peddersen, Inst. für Biologie III, Universität Freiburg, D-7800 Freiburg, West Germany

In a parasitoid-host interaction in insects a virus-like particle (VLP) of the parasitoid wasp *Venturia* is known to protect the parasitoid's egg from being encapsulated by the hemocytes of the host *Ephestia*. Molecular analysis of VLP proteins showed antigenic similarity to a host protein which appears to be synthesized in hemocytes and secreted into the hemolymph where it adheres to the basal lamina of larval tissues. Indirect evidence suggests that the host protein inhibits encapsulation of foreign particles. This properties of the host protein can explain the role of the antigenically similar proteins in VLPs in protecting the parasitoid eggs.

Chelonus polydnavirus transcripts and proteins that mediate parasitization of *Trichoplusia ni*. Bernhard Hane* and Davy Jones, University of Kentucky, Dept. of Entomology, Lexington, KY 40546

Poly (A)+ mRNA from *Trichoplusia ni* larvae parasitized by *Chelonus* embryos was radiolabeled and hybridized to *Chelonus* polydnavirus DNA. DNA fragments that did hybridize were microinjected into freshly laid *T. ni* eggs and tested for the ability to complement a polydnavirus infection applied two days later, and to suppress larval hemolymph melanization. Poly (A)+ mRNA from parasitized *T. ni* larvae was hybrid-selected with interesting polydnavirus fragments. The proteins made after *in vitro* translation were biochemically and immunologically tested, and the ones that are relevant for mediating parasitization were identified.

Supported, in part, by NIH GM33995.

MICROORGANISMS IMPLICATED AS A CAUSE OF THELYTOKOUS PARTHENOGENESIS IN TRICHOGRAMMA SP. (HYMENOPTERA: TRICHOGRAMMATIDAE). R. Stouthamer*, R. F. Luck, Department of Entomology, Division of Biological Control, University of California, Riverside, California 92321, USA.

Thelytokous races, consisting of only females, are known from many species of Hymenoptera. However, some thelytokous wasps can produce males when they are exposed to high temperatures (>30°C). Thelytoky is generally thought to be a trait controlled by chromosomal genes. Here we show that in Trichogramma species, thelytoky is inherited through a cytoplasmic factor. We were able to distinguish between cytoplasmic and chromosomal inheritance by a series of backcrosses, resulting in females with chromosomes from a thelytokous line and cytoplasm from an arrhenotokous line. These backcrossed females reproduced by arrhenotoky, indicating that thelytoky is not chromosomally inherited. In subsequent experiments we were able to change the mode of reproduction from thelytoky to arrhenotoky, by exposing thelytokous populations of Trichogramma deion, T. pretiosum, T. chilonis and T. platneri for several generations to either high temperatures or certain antibiotics. These results make it likely that thelytoky in these wasps is caused by a temperature sensitive microorganism.

EXTRACELLULAR INSECTICIDAL ACTIVITY OF XENORHABDUS LUMINESCENS STRAIN NC-19. David J. Bowen*², Miel A.E. Barman¹, Nancy E. Beckage¹, and Jerald C. Ensign². ¹Dept. of Entomology, University of Wisconsin, Madison, Wisconsin 53706 USA. ²Dept. of Bacteriology, University of Wisconsin, Madison, Wisconsin 53706 USA.

Xenorhabdus luminescens strain NC-19 is an entomopathogenic bacterium found in an apparent symbiotic association with nematodes of the genus Heterorhabditis. The bacterium is lethal to insect larva when injected into the haemocoel but not when ingested. The nematode is the vector for entry of the bacteria. Injection of cell-free growth liquor of 24-96 hr. cultures of X. luminescens was lethal to larvae of Manduca sexta. Heating the culture broth to 60°C for 15 min. destroyed the insecticidal activity. Analysis of the growth liquor by polyacrylamide gel electrophoresis (PAGE) under non-denaturing conditions revealed one major protein band. This protein hydrolyzed casein and gelatin. The protein, following elution from the gel, was found to be lethal to M. sexta larvae. Analysis of the protein by SDS-PAGE revealed 3 proteins of 58,000, 27,000, and 14,000 daltons. Proteolytic activity was associated with the 58,000 dalton protein. Each of the 3 proteins is now being tested for insecticidal activity.

PATHOGENICITIES OF DIFFERENT ENTOMOPATHOGENIC BACTERIA FOR ADULT TSETSE, GLOSSINA MORSITANS MORSITANS. G.P. Kaaya and N. Darji. ICIPE Research Centre, P.O. Box 30772, Nairobi, Kenya.

Pathogenicities of various entomopathogenic bacteria for adult tsetse were determined by feeding tsetse on rabbit ears smeared with bacteria and on blood containing bacteria using membrane feeding technique. The bacteria used in both experiments were: Pseudomonas aeruginosa OT 97, Serratia marcescens Db11, Bacillus sphaericus 1593-4, B. cereus BC 11, B. thuringiensis H-14, B. thuringiensis var israelensis 10216, B. thuringiensis 1 and B. thuringiensis 5. Mortalities in the smear experiments were not very high and only the following bacteria had caused significant mortalities by 8 days post-feeding: P. aeruginosa (72%), S. marcescens (70%), B. thuringiensis 1 (33%) and B. thuringiensis 5 (14%), compared to control mortality of 3%, and mortalities depended on the number of times tsetse were fed on the contaminated rabbit ears. In the membrane feeding experiment, tsetse fed once on blood containing 10⁴ bacteria/ul had very high mortalities by day 8 (92-98%) with most of the bacteria tested, except B. sphaericus (40%), which exhibited very low pathogenicity for tsetse in all experiments. Mortalities depend on the type of bacteria, concentration and on time post-ingestion.

USE OF THE BACTERIUM SERRATIA ENTOMOPHILA (ENTEROBACTERIACEAE) IN PEST MANAGEMENT OF THE NEW ZEALAND GRASS GRUB (COSTELYTRA ZEALANDICA) (COLEOPTERA; SCARABAEIDAE). T.A. Jackson, MAFTech, P.O. Box 24, Lincoln, Canterbury, New Zealand.

Serratia entomophila, the bacterium causing amber disease in grass grub, was first isolated in 1981. Population surveys showed the disease was widespread among grass grub and the level of disease increased with age of pasture. High levels of disease were associated with rapid population decline. Monitoring of disease levels in the population has allowed prediction of population trend. Populations declined when disease levels exceeded 30% in the previous generation. S. entomophila has been safely tested and registered for experimental use. The bacteria have been produced on a large scale by aerobic fermentation. Field trials have induced high levels of disease and given control equivalent to chemical insecticides. The bacterium is currently being developed commercially as a biological control agent for grass grub control.

POTENTIATION OF BACILLUS THURINGIENSIS AGAINST THE GREASY CUTWORM AGROTIS YPSILON (LEPIDOPTERA: NOCTUIDAE). H.S. Salama*, M.S. Foda, A. Sharaby, National Research Centre, Dokki, Cairo, Egypt.

Studies were conducted to search for biochemical means to enhance the potency of the endotoxin Bacillus thuringiensis var. galleriae HD-234, against Agrotis ypsilon so as to increase the feasibility of application and to lower the field spraying costs. In these studies, some compounds were tested including selected divalent salts of calcium, zinc and copper, some potassium and sodium salts, organic acid salts, protein solubilizing agents and amino acids. Some zinc, copper and calcium salts as well as potassium carbonate highly potentiated the effect of B. thuringiensis against the target insect. Some short-chained mono-carboxylic and dicarboxylic acid salts and some protein solubilizing agents showed also a similar potentiating effect. Among 21 amino acids tested, some of them greatly enhanced the endotoxin effect against the target insect.

THREE TYPES OF BACILLUS THURINGIENSIS CRYSTAL PROTEINS TOXIC TO LEPIDOPTERA. M. Peferoen*, H. Höfte and J. Van Rie, Plant Genetic Systems, J. Plateastraat 22, 9000 Ghent, Belgium.

Bacillus thuringiensis (B.t.) strains active against Lepidoptera, invariably contain crystal proteins of 130-140 kDa. Three types of crystal proteins are distinguished on the basis of the M.W. of the protoxin and the protease activated toxin, and the insecticidal spectrum. Type I crystal proteins are protoxins of 130-133 kDa, which are processed to 60 kDa toxins upon trypsin digest. Based on the restriction map of their genes, type I proteins are classified in three subclasses (4.5, 5.3 and 6.6 kb class). Toxins of the three subtypes are equally toxic to Manduca sexta and Pieris brassicae and have no detectable activity against Spodoptera littoralis. However, the 4.5, 5.3 and 6.6 subtypes differ in their toxicity against Heliothis virescens and Manestra brassicae. Type II crystal proteins are protoxins of 140 kDa with a tryptic core fragment of 55 kDa. These are only toxic to one of the 5 Lepidoptera tested (P. brassicae). Type III protoxins and toxins have a M.W. of 135 and 63 kDa respectively. Proteins of this type have a high toxicity against M. brassicae and S. littoralis.

A panel of 35 monoclonal antibodies (mabs) was used to compare the structural characteristics of the three different types of crystal proteins. Each type of crystal protein is associated with a typical reaction pattern, indicating a correlation between antigenic structure and insecticidal spectrum. The mabs were used to investigate the distribution of the three types among crystal proteins of 29 B.t. strains from 11 varieties.

THE MODE OF ACTION OF BACILLUS THURINGIENSIS DELTA-ENDOTOXINS: BINDING TO LEPIDOPTERAN MIDGUT MEMBRANES. H. Van Mellaert*, H. Vanderbruggen and C. Hofmann¹, Plant Genetic Systems, J. Plateaustraat 22, B-9000 Ghent, Belgium. ¹Inst. of Microbiology, Swiss Federal Inst. of Technology, Zurich, Switzerland.

Delta-endotoxins of the insect pathogen Bacillus thuringiensis cause lysis of midgut epithelial cells in sensitive insect species. Bt2, cloned from B. thuringiensis subsp. berliner was produced as a recombinant toxin in E. coli and was labelled with ¹²⁵I. The activated Bt2 toxin bound saturably and with high affinity ($K_d=0.5$ nM) to midgut membranes from the sensitive species Manduca sexta. Binding could be competed for by various other delta-endotoxins active on M. sexta, but not by toxins active on Diptera or Coleoptera. The Bt2 protoxin bound with lower affinity than the activated toxin. Binding experiments were also performed with another delta endotoxin from B. thuringiensis subsp. thuringiensis. Altogether our results indicate that the presence of specific receptor sites in the insect midgut may in part explain the differences in the insecticidal spectrum of B. thuringiensis strains.

SIMPLIFIED EXTRACTION AND PURIFICATION OF BTI. D.W. Misch*, Dept. Biol., Univ. N. Carolina, Chapel Hill, NC and D. Burnside, Dept. Biol., Lenoir-Rhyne Coll., Hickory, NC

A mixture of spores and crystals of Bacillus thuringiensis israelensis (BTI) was soaked in 0.17M Na-acetate for 1 hr. at rm. temp., then centrif. at 2,200xg for 10 min. The pellet was resuspended in 5ml of 0.2M NaOH and centrif. at 2,200xg for 10 min. The resulting supernatant contains solubilized larvicidal toxin; the pelleted spores have residual toxicity. The soluble toxin was precipitated by adding 5ml of 0.17M acetic a. to the supernate, then pelleted at 4,400xg for 10 min. For bioassay, the pellet was resuspended in 0.08M acetic a. For weighing and/or storage, 1ml aliquots of resuspended toxin were put into microcentrifuge tubes and spun at 15,000xg for 45 sec. The pellets were spin-dried under vacuum for two hrs. and weighed. The dried pellets could be resuspended in 0.08M acetic a. for bioassay or dissolved in 0.02M NaOH for protein assay. The extracted spores were also spin-dried and weighed prior to bioassay. Both the extracted toxin and spores were compared in bioassays with an international standard (IPS-82). Of the original toxic activity before extraction, 46% could be recovered. The extracted toxin contained 18,640 IU/mg, an approximately 2-fold increased activity. The IPS-82 assayed at 15,000 IU/mg. This extraction and purification can be completed within one working day.

CHITINOLYTIC ENZYMES PURIFIED FROM THE ENTOMOPATHOGENIC FUNGUS, NOMURAEA RILEYI. G. N. El-Sayed* and T. A. Coudron, USDA, ARS, P.O. Box 7629, Columbia, MO 65205-5001, USA.

Chitinolytic enzymes, produced by entomopathogenic fungi, are thought to assist the fungus in the penetration of the host cuticle. The presence of these enzymes has been correlated with virulence of the entomopathogens. Colorimetric assays were used to titer endochitinase and exochitinase activity during the growth stages of virulent and avirulent pathotypes of the fungus Nomuraea rileyi. Fractional precipitation, and affinity and ion exchange chromatography were used to isolate the two classes of chitin hydrolases from synchronized cultures of the fungus.

NATURAL AND MANIPULATED EPIZOOTICS OF NOMURAEA RILEYI (FARLOW) SAMSON (MONILIALES: MONILIACEAE) IN POPULATIONS OF SOYBEAN DEFOLIATORS FROM COASTAL ECUADOR. P.A. Stansly* and G.J. Orellana, International Programs, University of Florida, Gainesville FL 32611 USA.

Natural epizootics of this fungus commonly result in high levels of mortality in the noctuids Anticarsia gemmatilis Hubner and Pseudoplusia includens Walker before these defoliators cause economic damage to soybeans in Ecuador's coastal plain. Climatic conditions (high humidity and little sunshine), as well as elevated levels of inoculum resulting from successive cropping, are factors favoring fungal development. Artificial increases of inoculum in the field or inhibition with fungicides altered percent mortality caused by the fungus although no significant changes in number of defoliators were observed.

COELOMOMYCES UTAHENSIS: A MODEL SYSTEM FOR INTEGRATED MANAGEMENT OF MOSQUITO POPULATIONS. J. A. Shemanchuk* and H. C. Whisler, Agriculture Canada, Research Station, Lethbridge, Alberta, Canada, T1J 4B1 and Department of Botany, University of Washington, Seattle, Washington, U.S.A. 98195.

Coelomomyces utahensis is a parasitic fungus which is highly effective in killing mosquito larvae under laboratory conditions. This fungus is easy to propagate in vivo and survives a wide range of environmental conditions. This combination indicates an application of this fungus as a component of integrated management of mosquito populations in rock pool and small container situations.

SUPPRESSION OF NUCLEAR POLYHEDROSIS VIRUS INFECTION BY BETA-ECDYSONE IN THE SILKWORM, BOMBYX MORI L. R. F. Hou* and J. C. Yang, Department of Entomology, National Chung Hsing University, Taichung, Taiwan, R.O.C.

Suppression of Bombyx mori nuclear polyhedrosis virus (BmNPV) infection by β -ecdysone was studied using inoculation tests and the enzyme-linked immunosorbent assay (ELISA). Mortalities caused by BmNPV were lowest by injecting the 5th instar larvae of the silkworm with β -ecdysone at 0.4 μ g/larva before BmNPV inoculation. The larvae injected with various dosages of β -ecdysone had much lower ELISA values compared to those without hormonal injection, indicating that β -ecdysone is effective in suppressing BmNPV infection in B. mori. Hormonal suppression of BmNPV infection is more predominant by inoculating with lower viral dosages.

THE INSECT AND MAMMALIAN CELLULAR RESPONSES TO TOLYPIN,
A NEW ENTOMOPATHOGENIC METABOLITE FROM TOLYPOCLADIUM
SPP. V. Mařha, J. Weiser, A. Jegorov, J. S. Pillai,
F. Weyda, Z. Žižka Institute of Entomology, CSAV České
Budějovice Czechoslovakia.

Tolypin is a secondary metabolite isolated from fungi belonging to the genus Tolypocladium. The pure compounds is highly toxic to number of insects tested and it may have some potential for development as an insecticide. In this paper we are reporting on the effects of toxin on some mammalian and insect tissues at the cellular level. When administered orally to test insects the toxin appears to cause a severe vacuolization of the gut epithelial cells, followed by destruction of mitochondria. When injected into haemocoel of Galleria mellonella larvae, there is a rapid aggregation of hemocytes compared to control insects. The toxin appears to be of a peptidic nature with selective activity. The results of these studies and their possible implication will be discussed.

CULTIVATION AND APPLICATION OF VIRUS INSECTICIDES AGAINST AGRICULTURAL PLANT PESTS.
I. Zarinsh, Institute of Biology of the Latvian
SSR Academy of Sciences, 229021 Salaspils,
3 Miera Street, Latvian SSR, USSR.

Two new dry virus insecticides were cultivated: VIRIN-KSH for controlling Malacosoma neustria L. on fruit and forest leaf-bearing trees and on the sea-buckthorn, and VIRIN-Dipri. on for controlling the Neodiprion sertifer Geoffr. on pine trees. Experimental strains of nuclear polyhedrosis viruses are applied for the preparations. The preparation VIRIN-KSH was tested industrially for five years in various geographical zones of the USSR, and VIRIN-Dipri. on underwent an eight-year test in the north-west zone of the European part of the USSR. Both preparations showed a high activity: the technical efficiency was 70-100% at the incubation period of the infection 6-10 days. The preparations affect pests at all the stages of their development with a consequent aftereffect. A laboratory-industrial technology has been developed for their cultivation.

#70

THE EFFECT OF CONCENTRATION AND APPLICATION OF *BACILLUS THURINGIENSIS* AGAINST THE HOUSE FLY (MUSCIDAE, DIPTERA). Bedir Al-Azawi, Department of Biological Science, Science College Almustansiriyah Univ., Baghdad, Iraq.

The effect of three concentrations of *Bacillus thuringiensis* on second and third instar larvae, and adult house flies is described.

#71

DEVELOPMENT OF *CYDIA POMONELLA* GRANULOSIS VIRUS AS A COMMERCIAL PEST CONTROL AGENT. J. Ballard, D.J. Ellis and N.E. Crook*, AFRC Institute of Horticultural Research, Littlehampton, West Sussex, BN17 6LP, UK

The codling moth, *Cydia pomonella*, is a worldwide pest of apples, pears and walnuts. Conventional chemical control can deplete natural predators causing outbreaks of secondary pests such as spider mites. *C. pomonella* granulosis virus (CpGV) provides an effective alternative as a host-specific biological insecticide. Development of a product for commercial application has involved optimizing formulation and spray strategy.

Cost of purification necessitates the use of an impure preparation of CpGV based on a homogenate of infected laboratory reared *C. pomonella* larvae. A quantification system using ELISA has been developed for the impure product to complement time consuming bioassays used to measure the infectivity of a given batch.

Storage of insect viruses – particularly of impure formulations – is problematic at temperatures above 4–6°C. Drying procedures, packaging and the use of additives are being tested to limit degradation during room-temperature storage.

An optimum spraying strategy has been developed after trials of dose, volume and application frequency. Control in trials has been excellent.

#72

ABSORPTION OF *BACILLUS THURINGIENSIS* SEROVAR. *ISRAESENSIS* (B.t.i.) TO AQUATIC SUBSTRATES AND ITS PERSISTENCE IN COLD WATER. J. Boisvert* and M. Boisvert. Groupe de recherche sur les insectes piqueurs, Université du Québec à Trois-Rivières, C.P. 500, Trois-Rivières, Québec, Canada, G9A 5H7.

The persistence of toxicity from a B.t.i. based formulation (Teknar HPD) was studied in a Canadian pond. The pond was 2 m deep, slightly acidic and the temperature varied between 6°C to a maximum of 22°C during the course of the experiment (May to October). Water from the pond, two types of aquatic vegetation, sediments and glass slides colonized by periphyton were added to a diluted suspension of Teknar HPD, put in environmental chambers and placed near the bottom of the pond. Samples (liquid and solid fractions) taken at various time were bio-assayed with laboratory reared *A. triseriatus* larvae. All the liquid fractions were further tested for B.t.i. spores and total cell counts, and for proteases enzymatic units. The data indicated that with lake water the original toxicity took about 1 month to be reduced by half. In the presence of periphyton and sediments, toxicity disappeared more rapidly. For vegetation samples there was still 30% of the original toxicity, present in the liquid fractions after 3 months and one type of vegetation became highly toxic for up to 42 days. All the controls remained non toxic throughout the entire 6 months. Implication of spore, cell counts and proteolytic units will be discussed.

#73

TANGENTIAL ULTRAFILTRATION AS A MEAN TO STUDY BEHAVIOR OF *BACILLUS THURINGIENSIS* SEROVAR. *ISRAESENSIS* (B.t.i.) TOXIC PARTICLES IN STREAMS. J. Boisvert* and M. K. Kouassi. Groupe de Recherches sur les Insectes Piqueurs, Université du Québec à Trois-Rivières, C.P. 500, Trois-Rivières, Québec, Canada, G9A 5H7.

One of the major problem in studying the behavior of a particulate insecticide (B.t.i.), in running waters, is to quantify sublethal doses of the insecticide. Older B.t.i. formulations contained large number of spores and some people used their numeration to study dispersal of B.t.i. But spore counts did not really give informations on the dispersal of the B.t.i. particles and recent formulations have too little spores to be useful. Bioassays using mosquito larvae is better but accuracy is not good for values below the LC50 of the insecticide. Ultrafiltration with a Pellicon apparatus was used to study behavior (dispersion and removal) of the toxicity of a B.t.i. based formulation (Teknar HPD) after treatment of two small streams. Recovery of toxicity from water samples concentrated 20X was excellent in both cases (70–90%). Concentration of B.t.i. particles did not change its toxic properties as judged by the data obtained in bioassays with *A. triseriatus* larvae. Removal of B.t.i. toxic particles was very rapid starting from the point of application, then it would level off. The rapid removal occurred over a shorter distance in the small stream compared to the large one.

#74

MAKING OF MOLECULAR PROBES FROM *LYMANTRIA DISPAR* NUCLEAR POLYHEDROSIS VIRUS BY CLONING OF HIND III DNA FRAGMENTS AND UTILIZATION OF THESE PROBES FOR DIAGNOSTICS. Desmarteaux, D.*¹, Charpentier, G.¹, Arella, M.², Bourassa, J.-P.¹, Bellonck, S.², (1) Université du Québec à Trois-Rivières, Québec, (2) Institut Armand Frappier, Laval, Québec.

One pathology frequently observed in *Lymantria dispar* larvae is a viral epizooty caused by a nuclear polyhedrosis virus (NPV). This virus forms a part of the Baculoviridae group A. It contains a 130 kilobase pairs of DNA genome. Late in the infection cycle, the viral genome codes for a 30500 daltons polypeptide (polyhedrin) equivalent to less than 1% of the whole genome size. Corresponding portions of DNA from different NPV strains present homology from 80 to 90% for this polypeptide. Also, more than 10% of the whole genome shows a conformity between the different strains. From these data, the purification and extraction of DNA from USA strain of LdNPV allowed us to elaborate a genomic bank of fragments obtained with restriction enzyme Hind III. Molecular cloning of these fragments was undertaken with pBI 31 plasmid followed by an amplification in *E. coli* competent cell strain DH 5 α . Three of these clones containing small-size DNA inserts (0.85 - 1.30 - 1.85 Kbp respectively) were used as hybridization probes on isolated infected larvae samples issued from miscellaneous geographic sites, so as to verify and compare the specificity of each. The use of the specific probes for diagnosis of NPV will be discussed. The susceptibility of four cell lines to NPV was also tested.

#75

SURFACE PROPERTIES OF THE ENTOMOPATHOGENIC BACTERIUM *XENORHABDUS NEMATOPHILUS* ASSOCIATED WITH BACTERIAL ADHESION TO HEMOCYTES OF NON-IMMUNE *GALLERIA MELLONELLA*. G.B. Dunphy, Department of Entomology, MacDonald College of McGill University, Ste-Anne de Bellevue, P.Q. H9X 1C0.

The bacterium *Xenorhabdus nematophilus* (Enterobacteriaceae) is vectored into the insect hemocoel by the entomophilic nematode *Steinernema feltiae* DD136. The bacteria proliferate in the hemolymph and kill the insect.

Using chemical mutagenesis, it was possible to isolate *X. nematophilus* resistant to either the antibiotic polymyxin B or ampicillin. Only ampicillin resistant isolates were hypovirulent for larval *Galleria mellonella*. There was no correlation between bacterial virulence and the physicochemical properties of bacterial surface charge and hydrophobicity. Both antibiotic-resistant groups exhibited increased attachment to more granular cells than did the wild type. This was correlated with increased bacterial hydrophobicity and reduced negative charge.

#76

PERSISTENCE AND MODE OF ACTION OF *BACILLUS THURINGIENSIS* AGAINST *HELIOTHIS ARMIGERA* (LEPIDOPTERA: NOCTUIDAE). M. Hafez, H.S. Salama*, R. Aboul-Ela and M. Ragaei, Faculty of Science, Cairo University and National Research Centre, Dokki, Cairo, Egypt.

The half life of spores of *Bacillus thuringiensis* varies in different varieties. The decay in the persistence of spores was mostly correlated with the exposure time in the field. A biochemical approach was adopted to enhance the effect of *B. thuringiensis* var. *kurstaki* HD-1 against *Heliothis armigera* through optimization of the conditions present in the gut of the insect required for releasing intoxicating fragments of the pathogen, e.g., incorporation of potassium carbonate and phosphate increased the potency of the endotoxin against *H. armigera*. Investigations on the mode of action of *B. thuringiensis* showed that its parasporal crystals are affected by the mid gut juice of the insect and this is mostly correlated to the enzymatic activity. Heating the juice at 100°C caused an inactivation of proteolytic enzymes, while the addition of potassium carbonate increased its activity. It is clear that the activity of endotoxin is initiated by gut alkaline components and then further degradation of the crystals occurred through the protein enzymes.

#77

CHARACTERIZATION AND ECOLOGY OF *ENTOMOPHAGA MAIMAIGA*, A FUNGAL PATHOGEN OF THE GYPSY MOTH, *LYMANTRIA DISPAR*. A.E. Hajek*, USDA, ARS, PPRU, Boyce Thompson Institute, Ithaca, New York, USA 14853, M. Shimazu, Forestry and Forest Products Research Institute, Tsukuba Norin Kenkyu Danchi-nai, Ibaraki 305, Japan, R.S. Soper, USDA, ARS, NPS, Beltsville, Maryland, USA 20705.

A Japanese fungal pathogen of gypsy moth larvae displays unique isozyme patterns compared with closely related fungi, and has been described as a new species, *Entomophaga maimaiga*. The life cycle of this fungus includes an overwintering azygospore produced predominantly by later larval instars. Host specificity studies demonstrate that *E. maimaiga* is specific to the Noctuoidea, and especially the Lymantriidae. Sporulation, conidial germination, and disease incubation are optimal between 20-25°C. Conidial germination requires free water but 50% of conidia can germinate in only 3 hours under dark conditions.

#78

ECOLOGICAL INVESTIGATIONS OF PARASITIC MICROORGANISMS IN JAPANESE BEETLE, *POPILLIA JAPONICA* NEWMAN, AND ASSOCIATED SCARABAEIDAE. J.L. Hanula, Connecticut Agricultural Experiment Station, 123 Huntington St., Box 1106, New Haven, Connecticut, USA 06504

Seven parasitic microorganisms including 3 protozoa, 2 bacteria, a rickettsia and a fungus were recovered from 7 species of Scarabaeidae in Connecticut. The most common parasites were cephaline eugregarines observed in 5 scarab species. Eugregarines were found in Japanese beetle, *P. japonica*, at 42 locations and over 80% of the larvae were infected. *Adelina* spp. infecting 19% of the Asiatic garden beetles, *Maladera castanea* (Arrow), were found in larvae at 6 locations and in 2 other scarab species. A microsporidium, *Ovavesicula popilliae* Andreadis & Hanula, was found in 25% of the Japanese beetle larvae sampled and it was present throughout the state. *O. popilliae* reduced fecundity and slowed development of heavily infected individuals. The bacteria *Bacillus popilliae* Dutky and *B. lentimorbus* Dutky were recovered from 17 locations and 3.5% of the Japanese beetles were infected. *Rickettsiella popilliae* (Dutky & Gooden) was recovered from 5 scarab species at 2 locations.

In samples collected at 3 locations over 3 years *O. popilliae* and *B. popilliae* were the most common parasites of Japanese beetle.

#79

EFFECT OF INSECT HEMOLYMPH ON THE FORMATION OF NUCLEAR POLYHEDRA IN VITRO. H.Inoue*, T.Kanda, T.Tamura, W.Hara and K.Shimizul, The Sericultural Experiment Station, Tsukuba-shi Ibaraki, 305 Japan and 1) Katakura Kogyo Ltd, Matsumoto, Nagano 390 Japan.

A cell line of silkworm, *Bombyx mori*, (SES-BoMo-15A) had been cultured in the Mitsuhashi and Maramorosch's medium (MM) containing 3 % fetal bovine serum (FBS), and was directly switched to the MGM-443 media containing (1) 3 % FBS or (2) 10 % FBS and the MM media containing (3) 3 % FBS or (4) 10 % FBS. The tendency of cell growth in those media was same, however, the polyhedra formation was quite different when a *B.mori* nuclear polyhedrosis virus was inoculated to the cells. The percentage of cells formed polyhedra was (1) 6.5 %, (2) 11.9 %, (3) 0 % and (4) 0.1 % on day 5 post inoculation.

The hemolymph obtained from 5th instar silkworm larva was added up to 10 % to the MM media containing (3) 3 % FBS or (5) no FBS. The rate of cells formed polyhedra was markedly increased as (3) 17.7 % and (5) 20.2 % on day 3 post inoculation.

Thus, the addition of insect hemolymph into the medium promotes the formation of nuclear polyhedra in the silkworm cell line, but when it was autoclaved, it lost the promotive activities.

#80

STUDIES OF *BACILLUS MORITAI* FOR HOUSE FLIES CONTROL.

H.Iwahana*, S.Kubota, Department of Plant Protection, Faculty of Agriculture, Tokyo University of Agriculture and Technology, Fuchu, Tokyo, Japan.

Bacillus moritai is a bacterium which shows pathogenic for several flies, especially insecticidal effects against chemical insecticide resistant strain house flies.

Bacillus moritai is belong to *Bacillus cereus*, but differs in some bacteriological characteristics. This bacteria produces insecticidal, low molecular, water soluble, heat stable exotoxin. The mortality (LD50) of house flies was about 10⁵ spores/g (medium) by *Bacillus moritai*. The stability researches were made on *Bacillus moritai* dispersed to garbages left in outdoor and field soil. We could know *Bacillus moritai* spores have remained constantly in the field. There were no problems for other insects, fish domestic animals after safety tests, so it will be useful for house flies control as microbial insecticide.

#81

AMBER DISEASE CAUSED BY THE BACTERIUM *SERRATIA ENTOMOPHILA* (ENTEROBACTERIACEAE) - A DISEASE OF THE NEW ZEALAND GRASS GRUB *COSTELYTRA ZEALANDICA* (COLEOPTERA: SCARABAEIDAE). T.A. Jackson, MAF Tech, P.O. Box 24, Lincoln, Canterbury, New Zealand.

The bacterium, *Serratia entomophila*, was first isolated from the gut of the grass grub (*Costelytra zealandica*) in 1981. A study of the disease has shown that the bacteria are ingested from the soil by the larvae and colonise the foregut. A rapid cessation of feeding occurs and the gut clears producing a characteristic translucent amber coloration in the infected larvae. Once infected the larvae live for approximately 4 weeks at 20°C. Amber disease is unusual in that the bacteria are confined to the gut and do not invade the haemocoel until the final stages. Pathogenicity is dosage related and associated with adhesion of the bacteria to the intima of the foregut.

#82

THE EFFECT OF LARVAL PHASE ON SUSCEPTIBILITY OF THE ARMYWORM, *PSEUDALETIA SEPARATA* WALKER (LEPIDOPTERA: NOCTUIDAE) TO NUCLEAR POLYHEDROSIS AND GRANULOSIS VIRUSES. Y. Kunimi* and E. Yamada
Department of Plant Protection, Faculty of Agriculture, Tokyo University of Agriculture and Technology, Fuchu, Tokyo 183, Japan.

The larval susceptibility to nuclear polyhedrosis virus (NPV) and granulosis virus (GV) in the high and low density forms of *Pseudaletia separata* was examined under laboratory condition. With the rearing density decreased, the larvae were more susceptible and died earlier when 5th-instar larvae were perorally inoculated with NPV. The larvae reared in isolation were more susceptible than those reared in crowd when 2nd-instar larvae were perorally inoculated with GV. The pale larvae produced from crowded rearing were more susceptible than the black larvae when NPV was inoculated perorally. No differences in susceptibility and duration from inoculation to death were observed between the isolated larvae and the crowded larvae when NPV was inoculated subcutaneously.

#83

CONSTRUCTION OF MOLECULAR PROBES FOR THE DETECTION OF THE GRANULOSIS VIRUS OF THE IMPORTED CABBAGE WORM, *Pieris rapae*. P. Lepage*, S. Belloncik and M. Arella. Virology Center, Inst. Armand-Frappier, Laval, Québec, Canada, H7W 4V9.

The granulosis virus of the imported cabbage worm (PrGV) is, as most baculoviruses, a potential control agent for populations of insect pests. The development of a sensitive and specific detection method is of major importance in field testing of PrGV, as well as epidemiologic studies of this virus. The research presented here concentrates on the production of molecular probes directed to the PrGV genomic DNA. Five HindIII restriction fragments of the purified viral-DNA were cloned into pIBI, followed by amplification and purification of the recombinant plasmids. Probes were produced by primer extension of randomly primed denatured recombinant plasmid DNA in the presence of radioactive precursors. These probes were then used in hybridization assays with purified viral DNA, to assess specificity. Finally, PrGV specific probes were used to determine the presence of this virus in imported cabbage worm samples which were collected in the province of Québec.

#84

MICROBIAL CONTROL OF RICE PLANTHOPPER AND LEAFHOPPER BY ENTOMOPATHOGENIC FUNGI. T. Matsui*, T. Nose and M. Okada, National Agriculture Research Center, Kannondai, Tsukuba, Ibaraki 305, Japan.

The small brown planthopper, *Laodelphax striatellus*, and the green rice leafhopper, *Nephotettix cincticeps*, are important virus vectors in Japanese rice production. The planthopper and leafhopper populations are regulated by entomopathogenic fungi in paddy fields. In order to evaluate the effect of the fungi on the population regulation, insects were collected in a paddy field from July to October and fungi were isolated and identified from the dead insects during laboratory rearing. It was difficult to grasp general seasonal trend of diseased rate because of small sampling size. However, *Erynia delphacis* was easily observed from the insects. This fungus disease was recognized from the end of August to September and maximum rate of infection was four percent. In the laboratory, among some entomopathogenic fungus strains effective ones for the planthopper and leafhopper were also selected. A strain of *Metarhizium anisopliae* showed 96 % mortality in *N. cincticeps* and 77 % in *L. striatellus*. A strain of *Beauveria bassiana* killed more than 90 % of the planthopper and leafhopper.

#85

INFLUENCE OF GUT JUICE OF TARGET AND NONTARGET INSECTS ON THE DELTA-ENDOTOXIN OF THE COLEOPTERAN SPECIFIC BACILLUS THURINGIENSIS SUBSP. TENEBRIONIS. D. MEYER, H. STEINER and W. SCHNETTER, Zoologisches Institut, Universität, INF 230 D-6900 Heidelberg FRG.

The toxin crystals of *B.t. subsp. tenebrionis* (BTT) contain a delta-endotoxin with a molecular mass of 73kD or 66kD. The processing of the 73kD toxin to the 66kD form already is started within the sporangium and depends on fermentation conditions. Under certain conditions, toxin crystals consist only of toxin fragments smaller than 66kD. The crystalline toxin of BTT is highly toxic against first instar and second instar larvae of the Colorado potato beetle *Leptinotarsa decemlineata*. However the fourth instar larvae and the adults only stop feeding. Therefore we investigated in vitro the influence of gut juice on the delta-endotoxin and used SDS-PAGE and Western blotting for analyses of degradation products. The gut juice of all *L. decemlineata* stages has a pH between 5.0-6.0. It does not degrade the 66kD toxin, whereas the gut juice of *Locusta migratoria* (pH 5.3) digests the BTT toxin into small fragments. Our results do not explain the different susceptibility of young and old stages of *L. decemlineata* toward the delta-endotoxin.

#86

GROUND AND AERIAL APPLICATIONS OF NUCLEAR POLYHEDROSIS VIRUS FOR THE CONTROL OF SOME NOCTUID SPECIES. M. Okada* (National Agriculture Research Center, Yatabe, Tsukuba, Ibaraki 305, Japan), S. Makino (Kagoshima Agricultural Experiment Station), K. Nagai (Miyazaki Agricultural Experiment Station) and S. Yamamoto (Japan Agricultural Aeration Association).

Spodoptera litura, *S. exigua*, *Mamestra brassicae* and *Pseudaletia separata* are serious agricultural pests in Japan. Larvae of each species were the most susceptible to the NPV isolated from the identical species. Successful results of the *S. litura* control were obtained when the polyhedral suspensions of 1×10^{12} - 3×10^{12} /ha (130-390 LE) of the *S. litura* NPV (S₁NPV) were applied on the young instar larvae with the ultra low volume spray method. *M. brassicae* was satisfactorily controlled, when the suspension of 1×10^{12} PIBs/ha (100 LE) of the *M. brassicae* NPV was applied on the young instar larvae. In the cabbage field, twice applications of 1×10^{12} PIBs/ha could produce no damaged head. Young larvae of *P. separata* and *S. exigua* suffered by the application of 1×10^6 PIBs/ml of their own NPV. Ground and aerial applications of S₁NPV for the *S. litura* control were conducted in Kagoshima and Miyazaki Prefectures from 1984 to 1987. Although the polyhedral suspension of 2×10^{12} /ha could perfectly control the *S. litura* larvae in the ground application, the aerial application required 3×10^{12} PIBs/ha for the sufficient effect.

#87

HEMOLYTIC ACTIVITY IN *GALLERIA MELLONELLA* LARVAL HEMOLYMPH. D.J. Phipps*, J.S. Chadwick, and W.P. Aston, Department of Microbiology and Immunology, Botterell Hall, Queen's University Kingston, Ontario, K7L 3N6, Canada.

A heat stable hemolytic activity was identified in the hemolymph of normal and immune *Galleria mellonella* larvae. The hemolysin was active against sheep, human, guinea pig and rabbit erythrocytes. Hemolysis occurred in the presence of 0.04M EDTA and was not caused by the phospholipase and lysozyme activities present in the hemolymph. Vaccination of the larvae with formalized *Pseudomonas aeruginosa* increased the activity of the hemolysin. The increase and subsequent time-dependent decline of this activity followed the pattern of induced antibacterial activity that is characteristic of the immune response of the insect. The hemolytic factor(s) was partially purified by passage through Sephadex G-200 and was found not to be antibacterial. The physiological role of the hemolytic activity is as yet unknown. It is possible that it may act in consort with other hemolymph components to produce an immune state.

#88

FOUR YEARS SUCCESSFUL RESEARCH WORK ON PATHOGENS OF SOME AGRICULTURALLY AND MEDICALLY IMPORTANT INSECTS AND THEIR POSSIBLE USE IN BIOLOGICAL CONTROL. K. Purrini, National Coconut Development Programme (NCDP), Pest Control Section, Tanga, P.O. Box 5047, Tanzania.

A survey is given on pathogens infecting some agriculturally and medically important insects. During the investigations period (1983-1987), more than 70 species (most of them are new) were discovered in Tanzania and Yemen Arab Republic. Among them, many important parasites: one baculovirus isolate from *Spodoptera exempta*, 5 entomopox-virus isolates and 12 microsporidians from grasshoppers and locusts, 7 microsporidians and one protist from *Oryctes monoceros*, 13 microsporidians from *Anopheles* and *Culex*-larvae, a.o. were found to be associated with their hosts. Since high infection rates have been recorded, it is assumed that those pathogens play an important role as insect pests population density limiting factors. Conditions are discussed which may promote or check epidemics of those pathogens, but more research work on their life cycle, ways of transmission, the impact to their hosts and their application in the field, is required.

#89

FUNGAL CONTROL OF THE CARROT WEEVIL, *LISTRONOTUS OREGONENSIS*. T. Searle* & W.N. Yule, Entomology Department, Macdonald College, Ste. Anne de Bellevue, Quebec, Canada, H9X 1C0.

The variability of 10 isolates each of *Beauveria bassiana* and *Metarhizium anisopliae* was investigated for response to temperature, relative humidity and pH. Differences in response were found within, as well as between species. Each isolate was then tested for pathogenicity on each soil-inhabiting stage of the carrot weevil under optimal and sub-optimal laboratory conditions. LD and LT50 values varied significantly between the most and least virulent isolate of each species.

#90

SPRAY APPLICATION OF *VERTICILLIUM LECANII*. P.I. Sopp, A. Palmer, A.T. Gillespie & N.E. Crook, Institute of Horticultural Research, Littlehampton, West Sussex, UK. BN17 6LP.

Control of *Aphis gossypii* by the fungal pathogen *Verticillium lecanii* has proved to be unreliable in UK glasshouse chrysanthemum crops. The spores require conditions of high humidity, such as those on the underside of leaves, for germination. Conventional sprayers have difficulty in achieving good underleaf deposits. An electrostatically charged rotary atomiser was used in two experiments to apply a *V.lecanii* formulation to a glasshouse chrysanthemum crop. The deposits and subsequent aphid control were compared to those produced by a standard hydraulic sprayer. The electrostatic sprayer achieved higher deposits of spores and improved spore distribution with 32% of spores on the undersides of leaves compared to 14% with the hydraulic sprayer. In four comparisons of rate and timing the improved deposits resulted in earlier infection of the aphid population and lower peak numbers.

The use of electrostatic sprayers offers the opportunity to target microbial pesticides to the underside of leaves, where the pests are usually found and environmental conditions are more suitable.

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DETECTION OF GRANULOSIS VIRUS INFECTION IN *PIERIS RAPAE* POPULATIONS BY DNA HYBRIDIZATION TECHNIQUE. T.-L. Truong*, S. Belloncik and M. Arella, Institut Armand-Frappier, Université du Québec, Laval, Québec, Canada H7N 4Z3

Plot experiments were conducted to assess the potential of a Granulosis virus (GV) strain isolated in Quebec to control the cabbageworm populations and damages. Previous results demonstrated that viral DNA detection is more sensitive than microscopical examination, to diagnose a GV infection. Therefore DNA hybridization technique was performed in order to assess the efficacy of viral applications. Selected viral DNA probe labelled with biotin was hybridized to extracts of larvae collected from the plots and spotted on nitrocellulose filter papers. The filter papers were thereafter incubated with streptavidin-alkaline phosphatase complex and treated with bromo-chloro-indolyl-phosphate and nitroterazolum blue.

Using this methodology it was possible to estimate in the GV treated plots the exact percentage of the infected larvae, to study the evolution of the viral infection during the second, third and fourth generation of the insect and to confirm the GV infection in the death larvae collected. Moreover, the dissemination of viral infection in the control plots demonstrated by analysis at random of healthy-like larvae stressed the use of molecular hybridization technique rather than microscopical observations for the study of the viral infection, dissemination and persistence.

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ON THE FUNCTION OF THE p10 GENE OF *AUTOGRAPHA CALIFORNICA* NUCLEAR POLYHEDROSIS VIRUS. J.M. Vlak, F. van der Wilk, F.A. Klinkenberg, K.J.M. Zaal, J.B.F. Geervliet, M. Usmany, E.C. Klinge Roode, J. Roosien and J.W.M. van Lent. Department of Virology, Agricultural University, P.O. Box 8045, 6700 EM Wageningen, The Netherlands.

Two viral proteins are abundantly synthesized in *Autographa californica* nuclear polyhedrosis virus (AcMNPV)-infected *Spodoptera frugiperda* (Sf) cells: polyhedrin and p10 (MW 10 kd). Polyhedrin is the major constituent of viral occlusion bodies (polyhedra); the function of p10 is unknown. Using electron microscopy and immunogold labeling, it was demonstrated that p10 is associated with large fibrous structures in the nucleus and cytoplasm. In the nucleus these fibrous structures are frequently found associated with polyhedra.

Genetic manipulation of AcMNPV rendered recombinants where the p10 gene was inactivated and replaced by a p10-beta-galactosidase fusion gene for screening of recombinants. In Sf cells, these recombinants produced polyhedra that lacked a membrane. Fibrous structures were absent. In vivo, the recombinants were twice as virulent as wild-type AcMNPV. It is concluded that the fibrous structures are involved in the final stage of polyhedron assembly. The increased virulence of the recombinants maybe due to efficient dissolution of the polyhedra in the insect gut.

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A SECONDARY METABOLITE OF *TOLYPOCLADIUM* FUNGI WITH INSECTICIDAL PROPERTY. J. Weiser, V. Mařha, A. Jegorov, J.S. Pillai. Institute of Entomology, CSAV České Budějovice Czechoslovakia.

Our investigations show that several species of fungi belonging to the genus *Tolypocladium* produce a secondary metabolite for which we have given the name of Tolypin. This substance is found in variable quantities in different parts of the fungal mycelium and spores in several species of *Tolypocladium* we have examined. The quantity of metabolite expressed is also dependent on the type of media used for the fungal propagation. The toxin is highly lethal to mosquito larvae. Oral dosages of 500 - 5 ng ml⁻¹ of the pure toxin administered in aqueous solutions can cause death of larvae within few hours. This paper will describe the optimum conditions for the metabolite synthesis and discuss their likely impact on new bio-pesticide development.

TRANSMISSION OF LYME DISEASE SPIROCHETES. Joseph Plesman, Department of Epidemiology, University of Alabama at Birmingham, Birmingham, Alabama 35294, USA.

Ticks in the "*Ixodes ricinus* complex" appear to be the primary vectors of Lyme Disease spirochetes (*Borrelia burgdorferi*) around the world. *Ixodes ricinus* is the principal vector in Europe, *I. persulcatus* in Asia, *I. dammini* in the northeastern United States, *I. pacificus* in the northwestern United States, and *I. scapularis* in the southern United States. Although spirochetes have been found in other species of ticks (*Dermacentor variabilis*, *Amblyomma americanum*, *Dermacentor albipictus*, *Haemaphysalis* sp.), mosquitoes, and horseflies, the ability of these alternative vectors to transmit *B. burgdorferi* has not been documented. In the laboratory, *A. americanum* and *D. variabilis* larvae fed on *B. burgdorferi* infected hamsters did not maintain spirochetes transstadially. In contrast, *I. dammini* and *I. scapularis* maintained spirochetes transstadially, and efficiently transmitted infection to susceptible hosts. The biochemical and physiological basis for the apparently unique vector competence of ticks within the *I. ricinus* complex for *B. burgdorferi* should prove to be a fertile area of research.

THE ROLE OF SALIVA IN TICK-HOST INTERACTIONS. J.M.C. Ribeiro, Department of Tropical Public Health, Harvard School of Public Health, 665 Huntington Avenue, Boston MA, 02115, USA.

Natural tick-host associations are characterized by the ticks' ability to evade their host's defenses against tissue injury and bleeding. Inflammation, the complex repair reaction following tissue injury, may be further fired by immunopharmacological reactions triggered by antigens at the injury site. Vertebrate species vary in their repertoire of chemical mediators of inflammation and even in the relative proportion of effector leukocytes. It is proposed that saliva of ticks contain substances that specifically counteract their hosts' inflammatory mediators thus allowing successful feeding by the parasite. The implications of this concept to anti-tick vaccine development and cattle breeding will be discussed.

PROTEIN PHOSPHORYLATION AND REGULATION OF TICK SALIVARY GLANDS. J.R. Sauer*, J.L. McSwain, J.P. Williams and R.C. Essenberg†, Department of Entomology and Biochemistry†, Oklahoma State University, Stillwater, Oklahoma, U.S.A. 74078-0464.

After reception of the primary stimulus (dopamine), the salivary glands of feeding ixodid ticks utilize cAMP to help modulate cell activity during secretion. The best known mode of action of cyclic nucleotides in eucaryotes is to activate protein kinases that catalyze the phosphorylation of proteins. Many proteins in tick salivary glands incorporate ^{32}P when broken cell preparations are incubated with $[\gamma\text{-}^{32}\text{P}]$ ATP or when whole glands are incubated with ^{32}P . Cyclic AMP enhances the phosphorylation of some salivary gland proteins but also stimulates the dephosphorylation of others. Protein phosphatase activity is activated by cAMP. Activation by cAMP is attenuated by protein kinase inhibitor protein indicating involvement of a modulator phosphoprotein in activating protein phosphatase activity. Enzyme activity is also inhibited by $1\ \mu\text{M}\ \text{Ca}^{2+}$.

The results imply that modulation of protein phosphatases as well as protein kinases are central to controlling cellular function via reversible phosphorylation of proteins in response to Ca^{2+} and hormonal generated changes in cellular Ca^{2+} and cAMP.

CHARACTERIZATION OF SALIVARY GLAND PROTEINS USING RECOMBINANT DNA TECHNOLOGY. G.R. Needham, Acarology Laboratory, Department of Entomology, The Ohio State University, Columbus, Ohio 43210 U.S.A.

Complex salivary gland secretions of ixodid ticks provide for secure attachment and manage the inflammatory and immune responses of the host during a lengthy feeding interval. New approaches are being used to investigate the feeding process, both as a means for controlling ticks and understanding the physiology of the salivary gland which regulates the intimate host association. Immune sera from resistant sheep and rabbits, and hyperimmune sera produced by rabbits were used to characterize feeding-specific antigens by Western blot analyses; and rabbit sera were used to select recombinant clones from an expression cDNA library prepared using salivary glands from 550 unfed female *Amblyomma americanum* ticks. Candidate clones are currently being screened and analyzed for the presence of inserts. To our knowledge this is the first expression library generated from acarine tissue. Our aim is to produce salivary gland polypeptides in sufficient quantity to determine their functions in the feeding process and their potential role as immunogens to protect hosts from tick feeding.

THE RELATIONSHIP BETWEEN FEEDING, VITELLOGENIN PRODUCTION AND VITELLOGENESIS IN THE TICK *DERMACENTOR VARIABILIS* Lewis B. Coons* and Rosemarie Rosell-Davis, Memphis State University, Memphis, TN, USA 38152

In *Dermacentor variabilis*, vitellogenin is synthesized by the fat body and the midgut, released into the hemolymph, and transported to the ovary where it is taken up via receptor mediated endocytosis to become the major egg yolk protein, vitellin. Production of vitellogenin by the female fat body and midgut is initiated by feeding. We used rocket immunoelectrophoresis to quantitate the amount of vitellogenin in the hemolymph of ticks during and after feeding. In mated feeding females, vitellogenesis, the uptake of vitellogenin by the ovary, begins during rapid engorgement. In unmated feeding females, detachment from the host initiated vitellogenesis. We could also induce ovarian uptake of vitellogenin by transplanting fed, unmated ovaries into mated, ovipositing females.

ACQUIRED RESISTANCE TO IXODID TICKS INDUCED BY TICK CEMENT ANTIGEN. S.Z. Shapiro* and W.P. Voigt, International Laboratory for Research on Animal Diseases (ILRAD), Nairobi, Kenya. (Present address: Dept. of Veterinary Pathobiology, Univ. of Illinois, Urbana, IL, USA.)

Antisera from guinea pigs made resistant to infestation with an ixodid tick of East and Central Africa, *Rhipicephalus appendiculatus*, were used to identify the tick antigens they recognize by immunoblotting. Most of the antigens were found in tick salivary glands and in tick attachment cement. Antisera from *R. appendiculatus* resistant guinea pigs also recognized some salivary gland antigens in ticks of other species (*R. pulchellus*, *R. evertsi*, *Amblyomma variegatum* and *A. gemma*). Antibodies against the most strongly recognized *R. appendiculatus* antigen, a 20 kDa molecule, were only poorly reactive with similar sized molecules in the other ticks. A 94 kDa antigen, which appeared to have broader cross-reactivity, was purified from *R. appendiculatus* attachment cement and a monospecific rabbit serum was raised against it. This serum clearly recognized a molecule of similar molecular weight in *R. pulchellus* and *R. evertsi*. Intravenous inoculation of rabbits with the purified molecule elicited delayed type hypersensitivity to the antigen. The hypersensitive rabbits demonstrated resistance to feeding of *R. appendiculatus* ticks but slightly enhanced feeding of *R. pulchellus* ticks. These results are discussed with respect to their relevance for artificial induction of tick feeding resistance.

VACCINATION AGAINST BOOPHILUS MICROPLUS; LOCALISATION OF ANTIGENS ON TICK GUT CELLS AND THEIR INTERACTION WITH THE HOST IMMUNE SYSTEM. D.H. Kemp*, J.M. Gough, and P. Willadsen, CSIRO, Division of Tropical Animal Production, PMB 3, Indooroopilly, Queensland, Australia 4068.

Cattle express a variable degree of resistance to ticks after repeated infestations. The immune responses are not well characterised but are probably directed against salivary antigens and render the feeding site unfavourable. In contrast, vaccination using initially a multiplicity of antigens and subsequently purified antigens, stimulated immune reactions directed against the tick gut cells. In an in-vitro assay, the cells were damaged by antibodies alone but complement and possibly other components of the immune system are also involved.

The antigens have been located on the lumen plasma membrane of the gut digest cells using indirect fluorescent antibody and immunogold techniques. One immediate effect of antibody binding to the membrane appears to be inhibition of endocytosis by clathrin coated pits and vesicles. This preceded obvious damage to the membrane and could be shown by giving ticks a two hour pulse of immune serum followed by a marker of endocytosis.

TICK-HOST INTERACTIONS FOR IXODES HOLOCYCLUS: THE ROLE, BIOSYNTHESIS AND NATURE OF ITS TOXIC AND ALLERGENIC SECRETIONS. Bernard F. Stone*, Keith C. Binnington* and Maryann Gauci*, CSIRO, *Division of Tropical Animal Production, Long Pocket Laboratories, Private Bag 3, Post Office, Indooroopilly, Queensland 4068, Australia; and CSIRO, *Division of Entomology, GPO Box 1700, Canberra City, A.C.T. 2601, Australia.

The Australian paralysis tick Ixodes holocyclus occurs along the eastern coast of Australia and causes the serious toxicosis, tick paralysis in domestic pets and livestock as well as hypersensitivity reactions in humans. The former effect in animals is usually fatal in the absence of speedy antitoxin treatment and the latter may result in life-threatening anaphylaxis in humans. The protection of such hosts against toxic or allergic effects by vaccination or desensitisation respectively is the objective of current CSIRO research. The mechanisms of biosynthesis of the paralysing toxin (holocyclotoxin) and of the allergens will be discussed in relation to salivary gland structure and function. Recent research on the nature of the allergens will also be described.

IMMUNOLOGY OF INTERACTIONS BETWEEN TICKS AND LABORATORY ANIMALS. J.R. Allen, Department of Veterinary Microbiology, University of Saskatchewan, Saskatoon, Canada. S7N 0W0.

Guinea pigs, mice and rabbits have been shown to acquire resistance to ixodid ticks. Resistant animals prevent most of the challenging ticks from obtaining a normal bloodmeal.

This resistance is immunologically mediated. It is expressed only after a primary infestation and at sites different from those used in the primary infestation. Resistance can be transferred passively with serum, or adoptively with cells from resistant animals. It can be induced artificially using antigens extracted from tick tissues.

Naturally acquired tick resistance is associated with complex cutaneous hypersensitivity reactions to antigens in the saliva of the tick. Basophil leukocytes appear to have an important role in the mechanisms of this tick resistance. In resistant animals these cells accumulate in large numbers in the skin, beneath tick attachment sites. On contact with the specific antigen, they degranulate and release inflammatory mediators which appear to affect, directly and indirectly, the feeding behaviour of ticks attached nearby.

Langerhans cells in the epidermis of the host also appear to have some importance in both the acquisition and the expression of tick resistance. They trap the ticks' salivary antigens and present them to appropriate lymphocytes. They also may act as antigen-laden target cells in the epidermis of resistant hosts.

AREA WIDE INTEGRATED PEST MANAGEMENT OF CATTLE GRUBS: THE JOINT US-CANADA CATTLE GRUB PROJECT
P. J. Scholl, U.S. Livestock Insects Laboratory,
P. O. Box 232, Kerrville, Texas, USA 78029

The US-Canada Joint Cattle Grub Project was established in 1981. Participants were the USDA Livestock Insects Laboratory at Kerrville, TX, and the Agriculture Canada Research Station, Lethbridge, Alberta. The project had 4 primary objectives: 1) to determine if the use of systemic insecticides combined with release of sterile heel flies would eliminate Hypoderma from cattle within a defined area; 2) to determine if eradication was feasible and equally effective for both species; 3) to evaluate the economic benefits of cattle grub integrated pest management; and 4) to initiate supplemental studies on the biology, ecology, and control of Hypoderma spp. Insecticide application reduced cattle grub populations by more than 98%, and release of sterile flies eliminated Hypoderma entirely from a portion of the treatment zone. New approaches to integrated cattle grub population management will offer exciting alternatives in the future.

INTEGRATED APPROACHES FOR CATTLE FLY CONTROL.

J. Eric Hillerton, AFRC Institute for Animal Health, Compton, Berks., U.K., RG16 0NN

Flies from a variety of taxa are important pests of cattle compromising productivity or causing and transmitting disease. Effective means of control vary with the type of pest; ectoparasite, endoparasite or environmental nuisance, and its biology. The success and type of control also varies with the location and intensification (economic status) of the livestock industry. For efficient cattle farming, when resistance to insecticides is also considered, pests must be targeted according to their importance, source, site, ecology and the control necessary, with due regard to the environment. A number of examples of such integrated control necessary, and their consequences, will be considered.

INTEGRATED PEST MANAGEMENT OF STABLE FLIES AND HOUSE FLIES AT FEEDLOTS AND DAIRIES. J.B. Campbell, University of Nebraska West Central Research and Extension Center, North Platte, NE 69101 USA

The Integrated Pest Management program developed in Nebraska for fly control at feedlots and dairies integrates waste management, judicious use of insecticides, cattle lot design, good drainage, proper feed handling, weed control and cattle management into a system to reduce fly populations. The program has also integrated rodent and bird control and fly management where cattle and swine are maintained on the same farm. Current cooperative research (USDA/ARS, Nebraska and Kansas State University) is aimed at learning how to integrate animal waste management, insecticide use and biological control (pteromalid pupal parasites) simultaneously without one control system being detrimental to either of the others.

PEST MANAGEMENT OF BLOWFLY AND BODY LICE ON SHEEP. P.B. Hughes* and G.W. Levot, Department of Agriculture, New South Wales, P.M.B. 10, Rydalmere, N.S.W. 2116, Australia.

Control of the sheep blowfly, Lucilia cuprina (Wiedemann) (Diptera: Calliphoridae), is an excellent example of integrated pest management, incorporating animal husbandry, sheep breeding, use of insecticides and appropriate farm management. In contrast, control of the sheep body louse, Damalinia ovis (Schrank) (Phthiraptera: Trichodectidae) has relied almost exclusively on regular insecticidal treatments followed by management aimed at preventing reinfestation. The different approaches to the control of these ectoparasites reflect the biology of the pests, the nature of the damage they do and the social/human attitudes to the pests themselves. These aspects will be discussed in the light of recent developments affecting successful pest management of the sheep blowfly and the sheep body louse. The problem of pesticide residues in sheep by-products, the influence of the animal welfare/liberation movement and the evolution of insecticide resistance in both species have become major issues to be considered in implementing successful pest management programs.

IMPLEMENTATION OF INTEGRATED PEST MANAGEMENT PROGRAMS FOR POULTRY PRODUCTION. J.J. Arends North Carolina State University, Raleigh, North Carolina, USA 27695-7613

Utilizing IPM principles to manage pests associated with poultry production has been a goal of the scientific community as well as poultry production personnel. However, it has only been with recent changes in current trends of poultry production toward total confinement and the corresponding improvements in the level of management within these production units, that we have reached a point that the production system can be substantially manipulated and the full benefits of an integrated pest management program realized. The number of pest species in confined poultry production are usually few and the environmental conditions predictable. By manipulating environment, poultry husbandry techniques, bird density and movement, it is possible to implement IPM programs that give acceptable pest and ectoparasite control at the least economic loss and most effective pest control cost. The vertically integrated composition of the poultry industry allows the implementation of IPM programs across companies and production units. By implementing programs with production companies, rather than on a producer by producer basis, a larger number of birds and farms can realize the benefits of an IPM program approach. Program content and implementation approaches of poultry IPM programs will be discussed.

SHEEP KED-FREE PROGRAMS IN THE WESTERN UNITED STATES. J.E. Lloyd, Department of Plant, Soil and Insect Sciences, University of Wyoming, Laramie, Wyoming, U.S.A., 82071.

In the U.S.A. several western states have adopted state-wide programs to control the sheep ked, Melophagus ovinus (L.) (DIPTERA:HIPPOBOSCIDAE). Each state sheep association is developing its own voluntary program, and most have used the Wyoming model as a starting point. Reasons for the success of these programs include the increased value of lamb and lamb pelts, as well as the ease of sheep ked control with pyrethroid insecticides.

SWINE PEST MANAGEMENT. R.E. Williams, Department of Entomology, Purdue University, West Lafayette, IN 47907.

With trends to confinement production systems arthropod pests of swine are of increasing concern. Hog lice, Haematopinus suis (Linnaeus), and sarcoptic mange mites, Sarcoptes scabiei (De Geer) are the most common external parasites found on hogs in most swine growing areas. Several troublesome fly species are also found around swine facilities. Among the more important species include Musca domestica Linnaeus, and Stomoxys calcitrans (Linnaeus).

In considering a control program for external parasites emphasis should first be placed on good management practices and maintenance of a good herd health program to aid in preventing severe louse or mite problems. When control is needed proper insecticide treatment should first be made to the entire herd. This can be followed by a herd maintenance program treating the sows when they go to farrowing, treating baby pigs when they leave farrowing, treating boars every couple of months, and treating any new animals when brought into the herd. An effective fly control program constitutes proper sanitation and manure management practices, physical and biological control components, and suitable chemical control practices.

HISTORICAL DEVELOPMENT OF MEDICO-LEGAL ENTOMOLOGY. Robert D. Hall, Department of Entomology, University of Missouri, Columbia, Missouri 65211 USA.

Medico-legal, the major subdivision of forensic, entomology, uses data on life history and development to facilitate solution of possible criminal activity. The development of fly larvae is temperature driven; accurate identification of species and stage, with weather data, permits estimation of the time a dead body has been exposed to invading arthropods. An old reference on fly attraction to blood on weapons is known, but modern medico-legal entomology began with Bergeret's 1855 use of insect fauna to solve a child's murder. Megnin laid the groundwork during the late 1800s in a series of papers on the fauna of cadavers; most of the ensuing published case studies are European. Because the calliphorids are so important a part of the decomposer community, U.S. medico-legal entomology lacked a sufficient data base until a monograph was published in 1948. During the past decade, research has been devoted to degree-hour models for most important North American blow fly species, and coordinated research was begun using defined model systems to evaluate arthropod succession on swine corpses in various regions of the U.S. A bibliography is available and a training manual for law enforcement personnel is being prepared. The first monograph on forensic entomology was published in 1986.

CARCASS DECOMPOSITION AND EARLY ARTHROPOD SUCCESSION B. Morris, P.O. Box 48, Seaton, South Australia 5023

Many workers since Megnin (1894) have defined a number of stages of decomposition related to observable differences in carcasses through time. A study of pigs and sheep showed decomposition affected by numerous factors including season, species of carcass, insect attack, local environment and change in orientation after death. The conclusion is that the decomposition stages, although predictable in sequence, are not precise as indicators of time since death. For the purpose of demystifying the language used by forensic scientists in the presentation of information to jurors, police, judges and the public, the adoption of a common terminology in describing decomposition stages is recommended and Reed's (1958) four stages are advocated.

A number of workers have studied arthropod succession in a variety of carcasses. Few, however, have set up specifically for that purpose or have experimented in an acceptable form. Using pigs and sheep for comparison, the results of these authors have been examined with the conclusions that the time of arrival and sequence of the various larval stages are the most useful indicators and visitation time of many arthropods, including blowflies, can be erroneous. However, relating expected stages in succession to stages in decomposition may be useful in revealing information on the tampering with or movement of cadavers.

Succession remains a poor indicator of time since death compared with the developmental stage of fly larvae.

A TROPICAL APPROACH TO YORICK'S SKULL: THE LATER STAGES OF DECOMPOSITION. M. LEE GOFF, Department of Entomology, University of Hawaii at Manoa, Honolulu, Hawaii, USA

The fauna associated with remains during later stages of decomposition, that period after day 14 postmortem interval, is more variable than that encountered during earlier stages of decomposition and frequently not as intimately associated with the process. Diptera associated with early decomposition stages are replaced by various taxa of Coleoptera and, later, other Diptera, followed by soil-dwelling taxa, particularly the Acari. Accuracy of postmortem interval estimates decreases with temporal distance from death due to variations in species involved in the decomposition process and variations in their arrival at remains. Environmental factors exert greater influences on the process during the later stages of the decomposition process and remains cease to function as the closed systems characteristic of earlier stages. Case studies from the Hawaiian Islands with confirmed intervals of 19.5, 34 and 52 days will be presented to illustrate techniques in estimation of postmortem intervals during the later stages of decomposition and in tropical situations.

FORENSIC APPLICATIONS OF CALLIPHORID FLY BIOLOGY. Bernard Greenberg, Department of Biological Sciences, University of Illinois at Chicago, Chicago, IL, U.S.A. 60680.

Calliphorids are typically the first entomofauna at a homicide; because most bodies are discovered in the first few weeks, we focus on calliphorid biology to estimate postmortem interval. The lab developmental schedule of *Phaenicia sericata* illustrates forensic applications and problems. Lab-derived schedules may not reflect the thermal history of fly stages on a body. Sun/shade differences are illustrated by accumulated degree hours in rabbit carcasses. Maggot mass is another thermal variable. Collective metabolic heat of 2nd and 3rd instars can elevate temperatures well above ambient to confound so-called constant temperature rearings. Taking these factors into account, the maggot size - temperature relationship is a good measure of the age of an actively feeding larva. Growth stops in postfeeding larvae and may actually regress. An age marker for this stage is the ratio, larva length:crop length. Post-pupariation markers include: puparial color changes; pupal molt; eversion of head and respiratory horns in the transition from cryptocephalic to phanerocephalic pupa; ontogeny of pharate adult; and changes in the postemergent fly.

INSECT INDICATORS ASSOCIATED WITH PIG CARRION STUDIES AND DEATH SCENE CASES IN INDIANA: A SEASONAL COMPARISON. N. H. Haskell* and R.E. Williams, Department of Entomology, Purdue University, West Lafayette, Indiana 47907.

The need for regional carrion studies and increased knowledge of the Calliphoridae and other insect groups associated with these studies is imperative, due to the great variability in climate, habitat, and species diversification in the geographic U. S. Pig carrion studies were conducted during the spring, summer, and fall of 1985 and 1986 in northwest Indiana. The 50 lb. pig model was chosen for use in the evaluation of primary indicator species, insect succession, rates of decomposition, and climatological data controlling these biological processes, but it was not known how closely the pig model represented similar processes in actual human death scene cases. Death scene investigations were conducted throughout the state of Indiana during 1985, 1986, and 1987. Several cases investigated during this time were compared on a seasonal basis with the pig model with regards to primary indicator species, and succession. The death scene investigations proved to be very consistent with the pig carrion studies regarding the calliphorid species encountered, other indicator species present, the developmental time intervals involved, and insect succession, when considering the season of the year and the habitat in which the victims were discovered.

INVESTIGATIONS OF THE DIPTERA INFESTING THREE HUMAN CORPSES OF KNOWN POSTMORTEM INTERVAL. T.R. Adkins, Jr., Professor Emeritus, Department of Entomology, Clemson University, Clemson, SC 29634.

Using the degree-day formula, the life cycle of *Calliphora vicina* Robineau-Desvoidy [Calliphoridae] indicated that a corpse had been buried under a house for 15 days which concurred with the killer's confession.

Two corpses, one buried in a sleeping bag and the other found on the surface of the ground, were infested exclusively with larvae of the black soldier fly, *Hermetia illucens* (Linnaeus) [Stratiomyidae]. The killer confessed that the corpse in the sleeping bag had been buried 168 days. The first adult *H. illucens* emerged 21 days after exhumation. The corpse on the surface of the ground was that of a person who had wandered away from a confinement area, and the date of death is known within 3 days. The corpse was discovered by a hunter 75 days after disappearance, and the first adult *H. illucens* emerged 32 days after discovery of the corpse. Life cycles of *H. illucens* in other media will be compared to those in the corpses. These two finds of *H. illucens* in the human corpse are significant because only one other reported occurrence in a human corpse has been located in the literature (in the Canal Zone in 1915).

PROBLEMS IN PREDICTING THE PMI IN HOMICIDE INVESTIGATIONS. E.P. Catts, Entomology, Washington State University, Pullman, WA 99164-6432

Prediction of the post mortem interval (PMI) by using faunal succession in homicide investigations is based on a number of assumptions. Forensic entomologists must not become overdependent on a few quality baseline studies currently used to estimate the PMI.

A number of problems should be considered in using insects to estimate the PMI in homicide investigations. These include:

1. Insect activity in inclement weather and at night.
2. Timing of blow fly oviposition.
3. Mixed fly populations and staggered broods.
4. Seasonal effects on maggot development rates.
5. Effect of maggot generated heat.
6. Impact of species arriving out of sequence.
7. Availability of gravid blow fly recruits at the crime scene.
8. Effect of drugs, toxins, and parasitoids on maggot development.

Data supporting the reality of such problems will be given along with thoughts regarding how these questions might be studied.

RIGHTS, RESPONSIBILITIES AND ROLE OF A FORENSIC ENTOMOLOGIST IN A COURT OF LAW. C. L. Meek, Department of Entomology, Louisiana State University, Baton Rouge, Louisiana, USA 70803

Pretrial responsibilities of the forensic entomologist will be discussed relative to his/her role as a subpoenaed expert witness or an advisor to the attorney. Guidelines will be presented regarding: (1) the qualification process by which the court recognizes an individual as an expert witness; (2) the comportment of the expert witness while under cross examination; (3) the limitations of the testimony and (4) the rights of the expert witness. In addition, the responsibilities that the subpoenaing counselor has toward the expert witness/advisor for reimbursement of appropriate expenses and fees will be given. Several case studies involving forensic entomologists will be presented.

STATUS OF BIOLOGICAL CONTROL FOR SUPPRESSION OF LIVESTOCK PESTS. Richard S. Patterson, USDA-ARS-IAMARL, P.O. Box 14565, Gainesville, Florida 32604, USA.

The role of parasites, predators and pathogens, both naturally occurring and introduced, are discussed in relation to the population dynamics of arthropods affecting livestock and poultry. The degree of suppression in the average host population caused by bio control organisms and the degree of stability in the population following suppression of the host population is explained. Conclusions are illustrated from models where field data on natural populations have been affected by biological control organisms.

BIOLOGICAL CONTROL AS A COMPONENT OF POULTRY INTEGRATED PEST MANAGEMENT SYSTEMS IN THE UNITED STATES. Jeffery A. Meyer, Department of Entomology, University of California, Riverside, California, 92521, USA.

Poultry production in the United States makes use of high-density housing systems which often provide conditions conducive for the development of large populations of filth flies in the accompanying manure accumulations. Integrated control programs for filth flies associated with poultry production are generally based upon chemical, cultural, and biological control components. Parasites and predators of immature filth flies are important biological control agents, and proper cultural practices encourage maximum population densities. A wide variety of beneficial arthropods have been identified through surveys conducted in various styles of poultry housing throughout the United States. Pupal parasites in the family Pteromalidae have received the greatest research interest, in regard to their manipulation for enhanced biological control. Several species/strains of pteromalid parasites are available from commercial insectaries, to augment the endemic population. Further research is needed to determine the prospects for manipulating other beneficial arthropods, such as predacious mites and the predatory histerid, Carcinops pumilio.

BIOLOGICAL CONTROL OF HOUSE FLIES ON POULTRY FARMS IN SAO PAULO STATE, BRAZIL. E. Berti Filho (Brazil)

No Abstract

THE EFFECT OF FEEDING SYSTEM ON THE DIPTEROUS FLIES AND PREDACIOUS MITES INHABITING DUNG OF FARM ANIMALS. E.T.E. Darwish*, A.M. Zaki and A.A. Osman, Plant Prot. Dept., Menoufia Univ., Shebin El-Kom, Egypt.

The relationships between ration components and dipterous fly larvae and predacious mites inhabiting dung of farm animals were studied and discussed. A positive result was detected between wet rations and dipterous fly larvae; opposite result was noticed according to predacious soil mites.

It is easily supposed that dipterous fly larvae in manure would be available as foods for predacious soil mites. However, certain species of the families Macrochelidae, Rhodacaridae, Parasitidae, Uropodidae and Cheyletidae are predacious on flies larvae and play a role as a biocontrol agent.

THE BIOLOGY OF A NEW PARASITE OF FILTH FLIES. H.H. Hoyer (France)

No Abstract

EVALUATION OF THE USE OF MUSCIDIFURAX RAPTOR PARASITOIDS AND BAITED TRAPS TO MANAGE HOUSE FLY POPULATIONS ON DAIRY FARMS. R. W. Miller*, ARS, USDA, Beltsville, Maryland 20705 and D. A. Rutz, Department of Entomology, Cornell University, Ithaca, New York 14853.

Dairy farms in Maryland and New York were surveyed to determine species of house fly pupal parasitoids present and relative abundance. Eight species were found, with three- Muscidifurax raptor, Nasonia vitripennis, and Splangia cameroni-predominating. M. raptor was chosen for laboratory colonization. In subsequent years, the following treatments were imposed on dairy farms alone or in combination: (1) weekly releases of 12-25 thousand M. raptor parasitoids, (2) baited traps placed around areas of high house fly breeding potential. Parasitoids were monitored with sentinel pupal bags; house fly populations were monitored with light traps and/or spot cards. Analysis of data on M. raptor recovered from the pupal sample bags indicated that the release program was successful in establishing this species on dairy farms. Baited traps caught large numbers of house flies, especially in July and August. House fly population data generally appeared to indicate lower numbers of house flies on treated farms than on untreated farms.

BIOLOGICAL CONTROL OF DUNG-BREEDING FLIES --- PESTS OF PASTURED CATTLE IN THE UNITED STATES. G. T. Fincher, USDA-ARS, Veterinary Toxicology and Entomology Research Laboratory, P.O. Drawer GE, College Station, Texas 77841, USA.

The horn fly, *Haematobia irritans* (L.), and face fly, *Musca autumnalis* DeGeer, cost U.S. livestock producers millions of dollars each year due to costs of insecticides, equipment and labor for insecticide applications, and in production losses. These non-native pests breed in dung of pastured cattle. Natural enemies of dung-breeding flies associated with cattle dung in the U.S. are numerous; however, they do not adequately prevent horn fly and face fly populations from reaching economic levels. Several exotic species of competitors, parasites, and predators of dung-breeding Diptera have been introduced to aid the existing fauna of natural enemies in controlling these pests.

BIOLOGICAL CONTROL POTENTIAL OF TWO INDIAN HYMENOPTERAN PARASITES FOR THE CONTROL OF SOME IXODID TICKS. G. Geevarghese

Laboratory and field studies were conducted on two encyrtid species viz. *Hunterellus sagarensis* Geevarghese and *Hunterellus* sp. indet. parasitizing ticks in India. Both show host specificity in nature, the former parasitizing the nymphs of *Haemaphysalis bispinosa* and the later of *Hyalomma a. anatolicum*. In laboratory experiments, *Hunterellus sagarensis* can parasitize certain other species of the genus *Haemaphysalis* found in the forested area where Kyasanur Forest disease is endemic. It can also parasitize species of the genus *Rhipicephalus*. *Hunterellus* sp. indet. can parasitize species of the genus *Hyalomma* only. Possible use of these two parasites for the control of ticks are discussed in the light of field observations, their host specificity and other biological features.

CONTROL OF BUFFALO FLY (*HAEMATOBIA IRRITANS EXIGUA* DE MEIJERE) POPULATIONS BY INTRODUCED DUNG BEETLES. A. Macqueen*, B.M. Doube, Division of Entomology, CSIRO, Private Bag No. 3, Indooroopilly, Queensland, Australia, 4068.

Twenty-three species of dung-burying beetles were introduced into northern Australia from 1968-82 to disperse cattle dung and enhance biological control of buffalo fly. Currently seven species have become established at Rockhampton in central Queensland. Buffalo fly and dung beetle populations were monitored each week, from 1972-85: the numbers of flies on each animal in a herd of 20 cows were counted visually, and dung beetle abundance was estimated using dung-baited traps. Evidence is presented that, in recent years, buffalo fly populations on cattle were reduced at times when the beetles were exceptionally abundant. This occurred mainly in spring and summer. The high reproductive rate of the fly promoted rapid population increases following episodes of intensive beetle activity, so that control was intermittent. These field data are an indication of benefits that may become more widespread as the dung beetles disperse into areas that they have not yet colonised.

BIOLOGICAL CONTROL OF FILTH FLIES IN CONFINED CATTLE FEEDLOTS USING PTEROMALID PARASITES. GERALD L. GREENE, SW Kansas Expt. Stat., KSU Garden City, Kansas, USA 67846.

Pteromalid parasites have been sold by commercial insectaries to cattle feedlots with the promise of fly control. To date, there has not been a documented case to demonstrate fly control following commercial parasite releases.

Investigations of parasite releases and natural populations of parasites have demonstrated that the wrong parasite species have been released and too few parasites to impact on the fly populations. Release of *Spalangia endius* Walker is effective in poultry houses, but not in high plains cattle feedlots where it is absent from natural populations.

The first successful experimental reduction of stable fly (*Stomoxys calcitrans* Curtis) populations was by releasing *Spalangia nigroaenea* Curtis. The numbers of parasites released reduced the fly population peak and delayed the peak occurrence. Approximately 50 parasites/animal were released, rather than the 5/animal currently being sold by commercial insectaries.

HYDROTAEA (OPHYRA) SPECIES AS POTENTIAL BIOCONTROL AGENTS AGAINST *MUSCA DOMESTICA* (DIPTERA) IN HUNGARY. R. Farkas, Parasitological Dept., University of Veterinary Sciences, Budapest and L. Papp*, Zoological Dept., Hungarian Natural History Museum, Budapest, Hungary H-1088.

The larvae of *Hydrotaea ignava* (Harris, 1780) (syn.: *Ophyra leucostoma* (Wiedemann, 1817)) were found to be aggressive killers (predators) of house-fly larvae in litter of caged-layer houses and in a pig farm. However, it was found that the number of imago reared from manure samples cannot be evaluated by the simple methods for interspecific correlations. A schematic model was set up for analysing the events in larval stages. The killing effect of *H. ignava* larvae was not obviously detectable against *Fannia canicularis*, the second pest there.

The effect of different larval instars of *Hydrotaea aenescens* (Wiedemann, 1830) against different instars of *M. domestica* was studied in the laboratory with promising results in order to adopt a correct view of the control potential of *H. aenescens* larvae against house-fly larvae. The effectivity in the reduction of the number of house-fly larvae was analysed in relation to the initial age of the larvae and to the different initial ratios of these two species.

NATIVE BIOCONTROL AGENTS AS A COMPONENT OF INTEGRATED PEST MANAGEMENT FOR CONFINED LIVESTOCK. J.J. Petersen, Livestock Insects Research Unit, USDA, Department of Entomology, University of Nebraska, Lincoln, Nebraska, 68583, USA.

Surprisingly little is known about the impact of native biocontrol on pest arthropods associated with confined livestock. Recent studies indicate that pathogens and predators have a major impact on the developing stages of house flies and stable flies. However, these agents are generally difficult to manipulate and little is known about the affects of management practices and insect control on their population dynamics. Pteromalid parasites, in contrast, can be more readily manipulated and the impact of environmental modifications can be measured. Recent studies will be discussed on overwintering, seasonal population dynamics, dispersal, habitat and host preference, and habitat modification of pteromalid parasites to increase their biocontrol potential will be discussed.

HOST-PARASITE RELATIONSHIP OF *DIRHINUS PACHYCERUS* MASI (HYMENOPTERA: CHALCIDIDAE), WITH PARTICULAR REFERENCE TO ITS HOUSEFLY CONTROL POTENTIAL. M. Geetha Bai, No. 68, 17th Cross, 19th Main, Vth Phase, J.P. Nagar, Bangalore-560 078, India.

Studies on various aspects of the biology of *Dirhinus pachycerus*, a pupal parasitoid of houseflies in the Indian sub-continent, are presented. The aspects dealt with include mating and oviposition behaviour, adult nutrition, longevity, fecundity, daily rate of oviposition, ovigenic cycle, sex-ratio, host selection in relation to host age, host size, superparasitism, elimination of supernumeraries, mass production, etc. Possibilities of utilizing this parasitoid in integrated housefly control programmes are discussed.

A SUCCESSFUL AUGMENTATIVE RELEASE OF *SPALANGIA ENDIUS* WALKER (HYMENOPTERA: PTEROMALIDAE) IN COMBINATION WITH CYROMAZINE (0.05%) AND METHOMYL (1.0%) PLUS (Z)-9-TRICOSENE (0.025%) TO CONTROL FIELD POPULATIONS OF *MUSCA DOMESTICA* L. (DIPTERA: MUSCIDAE) AT CAGED LAYER INSTALLATIONS IN SOUTH GEORGIA AND NORTH FLORIDA. Philip B. Morgan* and Richard S. Patterson

Augmentative releases of *Spalangia endius* Walker in conjunction with Cyromazine 0.05% and Methomyl (1.0%) plus (Z)-9-Tricosene (0.025%) against field populations of *Musca domestica* L. at caged layer installations in south Georgia and north Florida demonstrated that the *S. endius* releases were as effective as the combination of *S. endius*, Cyromazine and Methomyl plus (Z)-9-Tricosene. Monitoring the *M. domestica* 3rd instar larval population provided an accurate method of evaluating the effectiveness of the parasitoid releases.

BEHAVIOUR OF *SPALANGIA ENDIUS* - A PARASITE OF MUSCOID FLIES. M. J. Rice, Department of Entomology, University of Queensland, St Lucia, 4067, Australia.

A range of devices have been tested for assessing the relative attractiveness of volatiles from host puparia to Pteromalid parasites. The most effective of the tested devices is a "Flat Choicer", built from the tops of tissue culture plates. Details of the construction and application of the flat choicer are given, with methods for running choice tests. The attractiveness of pupal volatiles is demonstrated and the preliminary analysis of their character described. The results also suggest a constant in the attention switching behaviour of *Spalangia endius*.

THE ROLE OF COLEOPTERAN AND ACARINE PREDATORS IN HOUSE FLY POPULATION REGULATION IN POULTRY PRODUCTION FACILITIES. C. J. Geden, Department of Entomology, Cornell University, Ithaca, New York, U.S.A., 14853.

Poultry houses offer excellent opportunities for the exploitation of filth fly predators owing to limited animal movement, environmental constancy, and the stability of the fly breeding habitat. Accumulating poultry manure can support robust populations of a large guild of generalist and specialist predator species, especially coleopteran and acarine predators. Of these predators, the two most important house fly natural enemies are the histerid beetle *Carcinops pumilio* and the mite *Macrocheles muscaedomesticae*. *M. muscaedomesticae* populations are volatile and highly responsive to changes in dipteran and nematode prey availability. *C. pumilio* populations are more stable due to the beetles' long development time (3-4 weeks) and longevity (up to two years), and their proclivity for dispersal from prey-poor environments. Laboratory and field investigations have examined the influences of crowding levels, feeding history, interspecific interference, prey availability, and temperature on rates of destruction of house fly immatures by these predators.

MASS PRODUCTION OF THE PREDACEOUS MITE, *MACROCHELES MUSCAEDOMESTICAE* (SCOPOLI) (ACARINA: MACROCHELIDAE), A PREDATOR OF HOUSE FLY. C. C. Ho*, H. L. Cromroy and R. S. Patterson

A mass-production method was developed for the predaceous mite, *Macrocheles muscaedomesticae* (Scopoli). Using spent house fly media, frozen house fly eggs, and a nematode, *Protorhabditis* sp., 2500 mites could be produced in 8 days from 34.5 female mites at 30°C. Under these conditions, the generation time of this mite was 3.225 days and the mite population could increase as high as 69.85 times per generation. The relationship of the nematode to the rearing of *M. muscaedomesticae*, and the possible ways to improve the mass-production method were discussed.

BIOCONTROL OF *MUSCA DOMESTICA* LARVAE WITH *BACILLUS THURINGIENSIS* VAR. *THURINGIENSIS*. J.B. Jespersen, Danish Pest Infestation Laboratory, Skovbrynet 14, DK-2800 Lyngby, Denmark.

The exotoxin-producing *Bacillus thuringiensis thuringiensis* (B.t.t.) has been evaluated for control of housefly larvae. Earlier studies were made with a liquid formulation, while later studies were made with a wettable powder formulation. Laboratory tests showed that the efficacy of the formulations were dependent on the test substrate (artificial media, pig, hen or calf manure) and the age of the larvae. However, there seemed to be no cross-resistance between B.t.t. and traditional insecticides, including organophosphate, pyrethroid and DDT resistant strains. Tests also showed the most persistent effect in manure with a low content of dry matter compared to manure with a higher content of dry matter. In a laboratory test B.t.t. was effective for a long period if applied to manure and left undisturbed. If 5 or 10 per cent of the treated manure was replaced weekly with untreated manure, to simulate natural conditions, the same degree of effect was not obtained. In field trials, pig, hen and calf manure in different manure handling systems were treated at the recommended dosages. The immediate inhibitory effect on fly larval development was doubtful, and a satisfactory persistent effect was not observed. The lack of success in the field trials will be discussed in relation to reproduction of the bacteria, growth stimulating factors, recommended and lethal dosages, and the use of feed additives (antibiotics).

ENTOMOPHTHORA *MUSCAE* AS A PATHOGEN OF FILTH FLIES. B.A. Mullens, Department of Entomology, University of California, Riverside, CA 92521.

The fungal pathogen *Entomophthora muscae* has been known for over a century. Recent studies have attempted to quantify the impact of *E. muscae* on field populations of manure-breeding flies and to determine how the pathogen persists and how it is transmitted. Studies are complicated by the fact that *E. muscae* likely is a complex, and this aspect is being pursued. Substantial work has been done in the United Kingdom, Denmark and the U.S.A. (Michigan, New York, California). In California, *E. muscae* naturally infects the 4 most common flies inhabiting poultry manure: *Musca domestica*, *Ophyra aenescens*, *Fannia canicularis* and *F. femoralis*. The pathogen from each host tends to be host-specific, except both *Fannia* species are highly susceptible to the pathogen from the other *Fannia* host. In the field, patent *E. muscae* infections occur year-round in *Musca* and *Ophyra*, though most *Musca* cases are in fall. Prevalence of infection may exceed 80% at some sites. Temperature and host density appear to be important determinants of infection. Comparative studies are underway between a southern California form of *E. muscae* from *M. domestica* and the dominant *E. muscae* form from Danish *M. domestica*. Given variability in temperature tolerance, etc., there may be potential for introduction of exotic *E. muscae* strains.

SUSCEPTIBILITY OF MUSCOID FLY PARASITOIDS TO INSECTICIDES USED IN DAIRY FACILITIES. Donald A. Rutz* and Jeffrey G. Scott, Department of Entomology, Comstock Hall, Cornell University, Ithaca, New York 14853, USA.

The comparative susceptibility of four fly parasitoids, *Muscidifurax raptor*, *Urolepis rufipes*, *Spalangia cameroni* and *Pachycrepoideus vindemiae* to seven insecticides used in dairy facilities was determined. This information is presently being used in conjunction with known fly insecticide resistance levels and parasitoid seasonal activity patterns to develop treatment schedules that minimize insecticide usage, dampen the spread of fly resistance and maximize parasitoid survival and efficacy.

A WEATHER-BASED POPULATION DYNAMICS MODEL FOR THE HOUSE FLY (*MUSCA DOMESTICA* L.): THE EFFECTS OF PESTICIDE USAGE ON PUPAL PARASITE POPULATIONS. J. A. Hogsette* and D. G. Haile

A population dynamics model for the house fly is presented. The model is designed to run on personal computers and is based on surface weather data. Though not yet complete, the model simulates cycling house fly populations in open and environmentally enclosed poultry houses. Control factors include manure removal, use of adulticides and larvacides, and biological control with selected pupal parasites. Pesticides must be used carefully to prevent suppression and elimination of parasite populations, however, at times it is necessary to use pesticides to quickly reduce house fly populations to desired levels despite the detrimental effects suffered by the parasites.

PREDICTION MODELS OF TICKS IN AUSTRALIA AND AFRICA. R.W. Sutherst and G.F. Maywald*, Division of Entomology, CSIRO, Long Pocket Laboratories, PMB No. 3 Indooroopilly, Queensland, Australia 4068.

A group of deterministic computer models has been developed to describe the population dynamics and management of cattle ticks. The models range from simple, life-cycle or genetic models to generalized, climate-driven programs that are applicable to most species of multi-host tick species. In addition, an epidemiological model is being developed to explore the effects of tick control measures on the transmission of tick-borne diseases. The climate-driven models have been used to guide research programs and then to design control strategies in Australia and in eastern and southern Africa. Initially a climate-matching model CLIMEX is used to explore the climatic favourability of the area of interest as a preparatory step to detailed population studies. When the necessary ecological and economic data have been collected, the models are tuned to simulate the population dynamics of the tick species concerned in the region of interest. After adequate descriptions have been obtained, the models are used to search for economically optimal control strategies involving a choice of tick control methods.

COMPUTER SIMULATION OF BABESIA TRANSMISSION IN CONJUNCTION WITH A MODEL OF BOOPHILUS (IXODIDAE: ACARI) POPULATION DYNAMICS AND CONTROL. D. G. Haile, G. A. Mount and L. M. Cooksey, USDA-ARS, Insects Affecting Man and Animals Research Laboratory, Gainesville, Florida 32604, USA.

This presentation will cover the status of development of a comprehensive, weather-based model for computer simulation of *Boophilus* tick population dynamics and *Babesia* transmission to cattle. The tick model uses a dynamic life table and includes the effects of temperature, saturation deficit and rainfall on major biological parameters. The *Babesia* transmission model includes the interaction between infected larvae and susceptible hosts and between infective hosts and susceptible ticks. An age structure is maintained for the cattle population to account for the difference in the effects of the disease for hosts younger or older than 9 mo. The model program provides for vector control by acaricide dipping of cattle and release of sterile-hybrid ticks. The model software is implemented for use on IBM-PC or compatible microcomputers. Model refinement and validation studies are in progress.

POTENTIAL OF BIOCONTROL FOR LIVESTOCK AND POULTRY PESTS IN DEVELOPED COUNTRIES. R. C. Axtell, Department of Entomology, North Carolina State University, Raleigh, North Carolina 27695-7613, USA.

Uses of parasites, predators and pathogens for control of filth flies, pasture flies, mosquitoes, and other arthropod pests of livestock and poultry are analyzed in relation to the animal production systems. The socio-economic, technical and political factors affecting choices in the use of control strategies are related to prospects for using biocontrol agents. Integrated pest management (IPM) programs which incorporate biocontrol agents for key pest species are presented as the best approach to maximum use of biological control in livestock and poultry production.

STUDY STATUS OF BIOLOGICAL CONTROL OF THE FILTH FLIES IN CHINA. Xue Ruide. Shanxi Medical College, Taiyuan, Shanxi, China

Study status of biological control of the filth flies in China are presented. It consists of predators (*Macrocheles muscaedomesticae*, beetles), pupal parasites (about 20 species of wasps), entopathogenesis (bacterial, hormone), and so on. Life history, behavior, some ecology and mass rearing of predominant natural enemies are introduced.

PROSPECTS FOR BIOLOGICAL CONTROL OF MUSCOID PESTS OF LIVESTOCK AND POULTRY IN DEVELOPING COUNTRIES. T. Sankaran, c/o Commonwealth Institute of Biological Control, Bangalore 560 032, India.

Musca domestica and certain other allied flies breeding in organic wastes pose a constant threat to livestock and poultry farming in India and other developing countries. In most situations where they occur chemical pesticides are uneconomical or unsafe to use continuously. Parasites and predators of these pests have been investigated in several areas and some of them successfully used in fly control on an experimental scale. Prospects for the use of native natural enemies and also for the exchange of promising additional species between different geographical regions are discussed.

THE EVOLUTION OF PARASITISM IN ARTHROPODS. YU.S. Balashov, Zoological Institute, USSR Academy of Sciences, Leningrad 199034 USSR

Parasitic Insecta and Acarina from an ecological group that is one of the richest in species of terrestrial Arthropods. Parasitism arose repeatedly and independently in taxa of different ranks of these animals. In its transitional forms (parasitoids, micropredators) it is most closely related to predation and less to phytophagy (lower Diptera, some Lepidoptera and Hemiptera) or to saprophagy (Sarcoptiformes mites). Ectoparasitism arose in two independent ways i.e. free-living Diptera and nidicolous Acarina and Psocidae. Transition to parasitism is irreversible and excludes a possibility to return to predation, phytophagy or saprophagy. Morpho-physiological characteristics of some Arthropods, e.g. piercing-sucking mouth-parts and wide range of digestive fermentative systems are preadapted to feeding on blood of vertebrates. Many families of Insecta and Acarina occupied a transitional ecological niche between predation and parasitism and became advanced groups with high species diversity and high numbers in the ecosystem.

PARASITIC ARTHROPOD - HOST IMMUNE INTERACTIONS. S.K. Wikel, Department of Microbiology and Immunology, School of Medicine, University of North Dakota, Grand Forks, North Dakota 58202, U.S.A.

Parasitic arthropod-host relationships are characterized by dynamic interactions and adaptations. Immunity to blood feeding ectoparasites is important in determining success of arthropod engorgement, pathogen transmission, and host reactions to infestation. Anti-arthropod immunity is related in part to the genetic composition and physiological status of the host, prior exposure to arthropod antigens and the magnitude of infestation. Hematophagous arthropods have developed mechanisms to counteract or suppress host immunity.

Parasitic arthropods effectively stimulate the host immune system and a variety of responses are elicited. This presentation examines host immunity to blood feeding arthropods, with emphasis placed on ixodid ticks. Host reactivity to arthropod immunogens involve soluble mediators of the inflammatory response, complement, antibody and cell mediated effector mechanisms. Hematophagous ectoparasites can induce host immunosuppression and immunoregulatory molecules occur in arthropod saliva. Immunological based vector control strategies are discussed. Supported by U.S. Department of Agriculture Grant Number: 85-CRSR-2-2617.

THE STRUCTURE OF PARASITIC ARTHROPOD COMMUNITIES, K. C. Kim, The Frost Entomological Museum, Department of Entomology, The Pennsylvania State University, University Park, PA 16802, U.S.A.

Parasitic insects and acarines on mammals and birds consistently show definite patterns in the community structure and guild memberships. The community structures of ectoparasitic arthropods on four species of sea birds, northern fur seal, white-footed mouse and Eastern cottontail rabbit are compared and general ecological paradigms proposed for the structure/function of ectoparasite community.

EVOLUTION OF SENSILLA IN PARASITIC ARTHROPODS.

S.B. McIver, Department of Environmental Biology, University of Guelph, Guelph, Ontario, Canada N1G 2W1.

Structure, function and number of sensilla of parasitic and free-living arthropods are compared.

ECTOPARASITES AND CLIFF SWALLOWS: A STUDY IN CO-ADAPTATION. Cluff E. Hopla, Department of Zoology, University of Oklahoma, Norman, Oklahoma 73019.

The Cliff Swallow *Hirundo pyrrhonata* is a New World hirundinid, inhabiting most of the Nearctic Region during the breeding season but overwintering in the Neotropical Region. The flea *Ceratophyllus celsus* is associated with the Cliff Swallow throughout much of the Cliff Swallow's range in the Nearctic Region. Boreally, *C. celsus* is replaced by *Ceratophyllus arcuegens*, and *Ceratophyllus scopulorum*. *C. Celsus* is present but is associated with *Riparia riparia*.

The ticks *Ornithodoros concannensis* and *Ixodes baergi* inhabit the cryptic spaces within the cliff and can go long periods of time (years) without a blood meal. The ability to withstand long periods of fasting is important because some colony sites have remained uninhabited for up to four years. Dependence of bugs, fleas and ticks upon the nest varies. Fleas are totally dependent up the nest, bugs less so and the ticks use it only as a feeding station; the vast portion of their lives are spent in cracks and crevices some distance from the nest.

EVOLUTIONARY BIOLOGY OF BOT FLIES. E.P. CATTS, Department of Entomology, Washington State University, Pullman, WA 99164-6432, USA.

Bot flies (Cuterebridae, Gasterophilidae, and Oestridae) are obligate myiasis producing parasites with three common characteristics: 1. a high level of host specificity, 2. infective larvae move from portal of entry to development site, and 3. specificity of development site.

This close interfacing of host and parasite suggests a very long relationship with ample opportunity for coevolved adaptations. The path for evolution of this myiasis is obscure, but probably arose from fly carrion associations and contact with open wounds and sores.

Most adaptive mechanisms appear to be parasite generated, without reciprocal host response. However host contact by infective larvae can result in an array of outcomes ranging from refractoriness, through aberrant and intolerant responses, to tolerant responses at optimal and suboptimal levels.

The presence or absence of a host immune response is concluded to be an important area of coevolution. Larval neutralization of a generic host immune response, though costly, reinforces the host specificity phenomenon.

PHYSIOLOGICAL ADAPTATIONS OF SUCKING LICE TO PARASITISM.
J.W. Maunder (UK)

No Abstract

ISOLATION, INTERFERENCE AND SPECIES BOUNDARY
MAINTENANCE IN TICKS. R.H. Andrews (Australia).

No Abstract

COEVOLUTION OF CHEWING LICE AND POCKET GOPHERS. R.A. Hellenthal*, Department of Biological Sciences, University of Notre Dame, Notre Dame, Indiana 46556, U.S.A., and R.D. Price, Department of Entomology, University of Minnesota, St. Paul, Minnesota 55108, U.S.A.

The New World mammalian family Geomyidae includes approximately 440 taxa of fossorial rodents. Investigations of the chewing lice that infest these hosts have examined more than 80,000 parasites from over 6,600 hosts and 3,600 localities throughout the geographic range of the pocket gophers. Data on host collection locality, host and parasite identifications and associations, and quantitative morphological characters for the lice are maintained and manipulated by a computerized host-parasite data management, taxonomic and distributional analysis, and geographic mapping system that has been used to evaluate and compare parasite populations and geographic distributions with those recognized for their hosts from morphological and genetic investigations by mammalogists. Studies of louse distributions and morphological character patterns in relation to host genetics in areas of host hybridization suggest that lice can accurately reflect host genetic isolation and patterns of gene movement. They also have been successfully used as indicators of host relationships, supporting fusions and reductions in the number of recognized pocket gopher taxa.

No Abstract

SEXUAL MATURATION AND REGRESSION IN FLEAS: THE
EVIDENCE OF HOST-SPECIFICITY. B.W. Williams (UK).

EVOLUTION IN TICKS (ACARI: IXODOIDEA). J.H. Oliver, Jr., Institute of Arthropodology and Parasitology, Georgia Southern College, Statesboro, Ga. 30460, USA.

Fossils, geographic distributions, host preferences, morphological parameters, developmental strategies, reproductive patterns, chromosomal complements, and genetic variances are analyzed among ticks and form the basis for proposal of a tick evolution model. A multi-nymphal, less synchronized life cycle, ability to produce sperm (and occasionally eggs) without a blood meal as an adult, relatively high chromosome numbers and an XX:XY sex chromosome system suggest that argasid-like ticks evolved earlier than did ixodid-like species. Morphological characters, chromosomal complements, sex chromosome systems, reproductive events and host associations suggest that Aponomma species retain more primitive characteristics than other ixodid species and that some species of Amblyomma, Haemaphysalis and Ixodes also possess some primitive traits.

a

VECTOR ASPECTS OF THE EPIDEMIOLOGY OF HUMAN ONCHOCERCIASIS IN LATIN AMERICA. A.J. Shelley, British Museum (Nat. Hist.), London, SW7 5BD, UK.

No Abstract

e

VECTOR BIOLOGY OF THE *SIMULIUM EXIGUUM* SPECIES COMPLEX AND *S. QUADRIVITTATUM* IN ECUADOR. M. Arzube, National Institute of Hygiene and Tropical Medicine "Leopoldo Izqueta Perez", Guayaquil, Ecuador.

No Abstract

b

VECTOR SIMULIID COMPLEXES (DIPTERA: SIMULIIDAE) OF HUMAN ONCHOCERCIASIS IN LATIN AMERICA. W.S. Procnier, British Museum (Nat. Hist.), London, SW7 5BD, UK.

No Abstract

f

BIOLOGY AND CONTROL OF THE PRIMARY VECTOR OF ONCHOCERCIASIS, *SIMULIUM OCHRACEUM* S.L. IN GUATEMALA. O. Ochoa A., National Eradication Service for Malaria (SWEM), Department of Onchocerciasis, Guatemala City, Guatemala.

No Abstract

c

CONTROL STRATEGIES FOR HUMAN ONCHOCERCIASIS IN THE AMERICAS. B.O.L. Duke, Department of Infections and Parasitic Diseases, Pathology, Armed Forces Institute of Pathology, Washington, DC 20306-6000, USA.

No Abstract

g

THE EFFECTS OF IVERMECTIN ON THE TRANSMISSION OF *ONCHOCERCA VOLVULUS* BY *SIMULIUM OCHRACEUM* S.L. FROM GUATEMALA. E.W.C. Cupp, Department of Entomology, Cornell University, Ithaca, New York 14853, USA.

No Abstract

d

THE EPIDEMIOLOGY OF ONCHOCERCIASIS IN ECUADOR: THE NEED FOR CONTROL. R. Guderian, Onchocerciasis Project, Health Care Division, Hospital Vozandes, H.C.J.B. Casilla 691, Quito, Ecuador.

No Abstract

h

EFFICACY OF CONTROL OF FLIES ON FARMED ANIMALS IN BRITAIN. J. Eric Hillerton, AFRC Institute for Animal Health, Compton, Berks., U.K., RG16 0NN

Some control of insects pestering/infecting farm animals in Britain is required by statute, warble flies and scab mites. Other insects are controlled to prevent disease, maintain the welfare and condition of the animals and for aesthetic reasons. A variety of insecticides applied as sprays, pour-ons, in ear-tags, as injections and dusts are licenced. The benefits of control and control strategies on sheep and dairy cattle will be presented.

i

A TECHNIQUE FOR QUANTITATIVE EVALUATION OF SOME ECTOPARASITIC MITES AND INSECTS OF DOMESTIC ANIMALS.

Y. K. Mumcuoglu, Department of Parasitology, Hebrew-University-Hadassah Medical School, Jerusalem 91010, Israel.

For the diagnosis and quantitative evaluation of ectoparasitic mites and insects of veterinary importance a modified KOH dissolution technique has been developed. Fifty intact skin sections from 10 different domestic animals were artificially infested with 10 specimens each of the mites *Sarcoptes scabiei*, *Chorioptes bovis*, *Psoroptes ovis* and *Demodex caprae* and insects *Haematopinus eurysternus* and *Bovicola bovis*. Sixty-seven to 88% of the mites and 80-99% of the insects were recovered by this technique. Using this method, parasitic mites and insects were found and identified in all skin scrapings from 10 naturally infested animals.

EXTERNAL MORPHOLOGY OF FLEA LARVAE (SIPHONAPTERA) AND ITS SIGNIFICANCE IN TAXONOMY. R.L.C. Pilgrim, Department of Zoology, University of Canterbury, Christchurch, New Zealand.

Examination of over 150 species of larvae from 10 families (representing ca 30% of known genera/subgenera) with phase-contrast and/or scanning electron microscopy reveals a much greater variety of detailed form than appears in the literature. Especially significant are: types of setae (at least 9 can be distinguished on the thorax and abdomen); setal patterns and numbers; form, arrangement and surface texture of sensory papillae on the antennal mound; and form and structure of the antennal shaft sense organ.

Some of these features appear to be characteristic of, and restricted to, tribes or higher taxonomic categories. Others, such as the shape and number of teeth of the mandibles, and the surface sculpturing of the integument, show considerable variation which does not follow recognised classifications based on adult fleas, but seems to be more related to factors in the biology of specific larvae.

SURVIVAL AND REPRODUCTION OF ARTIFICIALLY FED CAT FLEAS, CTENOCEPHALIDES FELIS BOUCHE (SIPHONAPTERA: PULICIDAE). S.E. Wade* and J.R. Georgi, Department of Immunology, Microbiology, and Parasitology, New York State College of Veterinary Medicine, Cornell University, Ithaca, New York, 14853, USA.

An artificial feeding system for adult cat fleas, *Ctenocephalides felis* (Bouche), is described. Survival and reproductive success of artificially fed fleas were attributed to continuous provision of blood at 37°C and a substrate that allowed the fleas to walk, but not jump. Fleas were confined for artificial feeding in any of three different types of cages, all of which were cylinders of clear plastic with nylon mesh cemented across both ends. The cages differed in dimensions and in the inclusion or lack of hair. The upper end of the cage was apposed to a glass insect blood feeder supplied with a Parafilm membrane through which the fleas were able to feed on cattle or dog blood. This system in conjunction with standard larval and pupal rearing techniques has resulted to date in a colony of 15 artificially reared generations.

WATER RELATIONS OF ADULT AND IMMATURE CAT FLEAS, CTENOCEPHALIDES FELIS (BOUCHE) (SIPHONAPTERA: PULICIDAE). A.G. Appel, Department of Entomology, Auburn University, Auburn, Alabama 36849-5413, USA.

Water relations including water content, cuticular permeability, rate of water loss, and desiccation tolerance of cat fleas, *C. felis*, were determined at 30°C and 0-2 %RH. Immature stages contain more water, have higher cuticular permeabilities and rates of water loss than do adults. All stages of *C. felis* are killed by % total body water losses of greater than 60%.

DEVELOPMENT OF CAT FLEAS, CTENOCEPHALIDES FELIS FELIS ON HOST ANIMALS. L.A. Lemke*, American Cyanamid, Shulton Research Div., Clifton, NJ 07015; P.G. Koehler, Dept. of Entomology & Nematology, Univ. of Florida, Gainesville, FL; and R.S. Patterson, USDA-ARS-IAMARL, Gainesville, FL.

No significant difference was found in the of eggs produced by cat fleas feeding on cats and those feeding on kittens. There was, however, a difference between individual animals. A pipette method was used to volumetrically collect and count eggs. This method only had a SE of 100 eggs per sample.

THE CAT FLEA, CTENOCEPHALIDES FELIS AS A POTENTIAL VECTOR OF MURINE TYPHUS. A.F. Azad, Department of Microbiology and Immunology, University of Maryland School of Medicine, Baltimore, Md. USA 21201.

The cat flea is a common and important ectoparasite of carnivores in many parts of the world. *Ctenocephalides felis* has been implicated as potential vector of murine typhus. Under experimental conditions, the cat flea acquires and transmit *Rickettsia typhi* (= *R. mooseri*), the etiologic agent of murine typhus as readily as does the putative vector, *Xenopsylla cheopis*. Data on the experimental infection of the cat flea with the rickettsiae will be presented and compared with two other vector species. Since *C. felis* is abundant in endemic foci and readily bites man and various other mammals, the role that this species plays in the transmission of murine typhus will be discussed.

FLEA ALLERGIES IN PETS. R.E.W. Halliwell (UK)

No Abstract

CURRENT CAT FLEA RESEARCH IN THE UNITED KINGDOM.
B. Williams (UK)

No Abstract

STUDY OF CTENOCEPHALIDES CANIS AND ARCHEOPSYLLA ERINECEI
ERINECEI IN IRELAND. K.P. Baker*, R. Mulcahy. Faculty
of Veterinary Medicine, Ballsbridge, Dublin 4, Ireland.

Flea hypersensitivity of dogs and cats is the most common presenting condition in the Clinic of the Faculty of Veterinary Medicine, Dublin. Hedgehogs are usually infested with fleas and these might be of importance in the epidemiology of flea hypersensitivity. However, no hedgehog fleas were isolated on dogs attending the Clinic in a course of one year. During the same period, of 18 infested hedgehogs examined all but one flea (*Ctenophthalmus nobilis*) was identified as *A. erinecei erinecei*. The results of intradermal tests of extracts of both species on hypersensitive dogs are compared.

STUDIES ON THE BIONOMICS AND HOST RELATIONS OF THE
FLEAS OF THE GENUS CTENOCEPHALIDES IN TAMIL NADU, INDIA.
S.A. Joseph, Department of Parasitology, Veterinary College, Madras,
India.

A faunistic survey of flea fauna of Tamil Nadu, India revealed a total of 16 species of fleas representing 6 families and 10 genera. In the genus *Ctenocephalides*, *C. canis* was restricted to dogs in high altitude, while *C. felis felis* and *C. felis orientis* were noticed in a wide range of hosts, irrespective of climatic conditions. The bionomics of *C. felis orientis* was studied in considerable depth. The seasonal variations of this flea, its host preference, its jumping ability, the feeding areas it selects on the host etc., were studied in detail. This flea produced three types of reactions on human volunteers. The males sucked less quantity of blood than the females and the time the latter spent on this act was more. This species was found in large numbers on cows and buffaloes, the flea index being higher on cows. The bullocks carried the least number. Copulation was observed frequently on the cows and rarely on bullocks. Fleas fed on pregnant cows and she buffaloes squirted out greater volume of blood and produced maximum number of fertilized eggs. The sex hormones seemed to influence the egg producing capacity of this flea. Experimentally, this flea was incriminated as an intermediate host for *Dipylidium caninum*. Fleas of this genus could not act as a mechanical vector for *Trypanosoma evansi* among the domesticated animals.

ECTOPARASITE SURVEYS IN IRAQ WITH EMPHASIS ON
CTENOCEPHALIDES SP. J. Abul-Hab (Iraq)

No Abstract

THE VETERINARY AND MEDICAL IMPORTANCE OF CTENOCEPHALIDES
SPEC. IN ISRAEL. Y.K. Mumcuoglu, Dept. of Parasitology,
Hebrew Univ.-Hadassah Med. School, Jerusalem, Israel.

The genus *Ctenocephalides* is represented by 3 species in Israel: *C. felis* (Bouché, 1835), *C. canis* (Bouché, 1926) and *C. arabicus multispinosus* (Smit, 1960). *C. felis* is a very common ectoparasite of cats and dogs and has also been found on a number of wild animals. 40% of dogs from a kibbutz and calves from 7 farms were infested with this species. *C. canis* occurs less frequently than *C. felis*. It probably caused the death of 11 lambs from a flock of 300 sheep. *C. arabicus multispinosus* has been found only on the rodent, *Procapra capensis*. *C. felis* was present in 9 out of 10 patients infested with fleas who were examined in the last 3 years. Only 5 of these patients had a dog or a cat in their homes. Stings were usually multiple and occurred in a characteristic pattern either clustered or dispersed in a linear form. The reaction was typified by an erythema and weal formation accompanied by severe itching followed by a late skin reaction which lasted up to 2 weeks. In 2 cases there was a secondary infection. Local treatment was given against the skin reactions and patients were advised to spray their homes with a pyrethrum containing preparation.

THE GENUS CTENOCEPHALIDES IN ISRAEL—BIOLOGY, IMPORTANCE

AND CONTROL. Shoshana Rosen, A. Hadani*, I. Yeruham and M. Ziv. Department of Entomology, The Kimron Veterinary Institute, Beit-Dagan, Israel.

Ctenocephalides canis (C.c.) and *C. felis felis* (C.f.f.) have been reported in Israel from dogs, cats, few carnivores and rodents. C.f.f. is by far the most widespread. In a study conducted since 1980, livestock, dogs and cats were found infested solely by C.f.f. while C.c. was rarely found on wild carnivores. Few C.f.f. type specimens showed mixed characters of the hind tibial spines of both species. Severe flea infestations are reported in summer and autumn while moderate ones can be encountered in winter. Flea breeding in Israel is mostly outdoors while indoor infestation is rare. Recently, severe C.f.f. infestations have been reported in lambs, kids and 1-3 month old calves. In dogs and cats C.f.f. causes severe irritation and atopic allergic dermatitis while in livestock a non-regenerative anemia is the main symptom, leading often to death. Control measures included thorough cleaning of corrals and application of pulgicides. Methoprene has been successfully applied when combined with adulticides.

INVESTIGATIONS ON *CTENOCEPHALIDES* SP. IN NIGERIA.
E.B. Otesile (Nigeria)

No Abstract

THE STATUS OF THE CAT FLEA IN DENMARK AND PROSPECTS FOR NEW METHODS OF PREVENTION AND CONTROL. Alice Olsen, Danish Pest Infestation Laboratory Skovbrynet 14, DK-2800 Lyngby, Denmark

The annoyance to people and pets of the cat flea *Ctenocephalides felis* has been escalating during the last two decades in Denmark. Plausible reasons for this situation are proposed. The same pattern of an escalating cat flea population has been reported from Sweden.

In recent years the Danish Pest Infestation Laboratory (DPIL) has tested the efficacy of a variety of antiflea formulations by counting the flea egg production from treated infested cats in the laboratory. The laboratory tests have been supplemented by extensive field trials with pets in homes.

Besides evaluating traditional insecticides for the control of Danish cat fleas, efforts have been made to improve the use of the "third generation insecticides".

The juvenile hormone analogue, methoprene, has for some years been used as a convenient non-toxic compound to prevent flea larvae from reaching the biting adult stage by treating premises. Recently it was discovered at the DPIL that this well-known compound had an additional ovicidal effect on flea eggs when treating the fur of cats and dogs. Perspectives of such treatments for preventive use will be discussed.

THE EFFECTS OF SYNTHETIC PYRETHROIDS ON *CTENOCEPHALIDES FELIS* IN TANZANIA. B.S. Kilonzo*, and D.N. Gisakanyi, Department of Veterinary Microbiology and Parasitology, P.O. Box 3109, Chuo Kikuu, Morogoro, Tanzania.

Ctenocephalides felis adults obtained from young goats were reared in captivity and the offspring were subjected to several tests with different formulations of permethrin. A total of 1260 fleas of both sexes and mixed ages were exposed to 0.005% permethrin powder for periods varying from 30 minutes to 24 hours. Mortality of 100% was obtained after exposing the insects for one hour. Likewise, white rats infested with 2400 fleas were kept in contact with the same concentration of the insecticide for 24 hours and all the insects were killed at the end of this exposure period. Additionally, fleas were exposed to permethrin-impregnated papers at concentrations of 0.45 and 0.9 mg/cm². These were all killed after 24 and 8 hours respectively. It was generally concluded that the pyrethroid was very effective against this flea species and hence it was suitable for controlling the ectoparasite in domestic animals, animal barns and residential dwellings in the country. Moreover it is easily available to most farmers as they are currently using it for controlling *Prostephanus truncatus*, a very devastating stored crop pest in the country.

Bioassay Techniques for the Evaluation of Insecticides Used in the Control of *Ctenocephalides felis* Bouché (Siphonaptera: Pulicidae) W.A. Donahue, Zoëcon Corporation Dallas, Texas U.S.A. 75234

Various bioassay techniques exist for the evaluation of flea control products used indoors, outdoors, and on animals. These techniques are used to evaluate new compounds, formulations, or delivery forms used in urban flea control strategies. A basic understanding of the fleas biology is critical in designing these bioassays and the interpretation of the results. These data are essential to product development, directions for use, and label claims on the finished product.

INSECT GROWTH REGULATORS FOR THE CONTROL OF CAT FLEAS, *CTENOCEPHALIDES FELIS*. P. G. Koehler, Department of Entomology & Nematology, Univ. of Florida, Gainesville, FL; R. S. Patterson, USDA-ARS-IAMARL, Gainesville, FL; and L. A. Lemke, Shulton Research Division, Clifton, NJ.

Two classes of insect growth regulators were evaluated for control of cat flea larvae. The chitin synthesis inhibitors provided in significantly higher mortality of first stage larvae than subsequent stages. The juvenile hormone analogs resulted in significantly higher mortality of third stage larvae. Field applications resulted in ca. 3 months control of fleas in outdoor and indoor environments.

A FILM ON THE LIFE CYCLE OF THE CAT FLEA. K. Keldsen (Denmark)

No Abstract

APPLICATION OF MODELLING AND OPTIMIZATION TECHNIQUES TO THE CONTROL OF BLACK FLY LARVAE (DIPTERA: SIMULIIDAE) IN RIVERS. C. Back*, A. Chalfour and J. Boisvert, Dép. de Chimie-Biologie, Université du Québec à Trois-Rivières, C.P. 500, Trois-Rivières, Québec, Canada G9A 5H7.

Hundred thousands liters of insecticide are applied each year in rivers for the control of black fly larvae. Dosage and spacing of treatment points is usually determined by trial and error, leading frequently to failure or overdosing. We decided to tackle this problem by modelling two major components of carry: black fly susceptibility to insecticides and transport of insecticides in rivers. We obtained data for the susceptibility model through lab and field bioassays. Transport was studied by treating rivers with insecticides and a tracer. Experiments were performed in Québec, and in West Africa in collaboration with the W.H.O. Onchocerciasis Control Programme. The susceptibility model predicts mortality from insect, insecticide, water and treatment parameters. The transport model predicts the dose of insecticide reaching any distance downstream of application, using discharge and river stage as parameters. Initially intended for B.t.i. treatments, the model is now being expanded to other operational insecticides. The integrated carry model enables to predict the efficiency and cost of any application, provided parameters are known. An algorithm has been developed allowing the optimization of both insecticide and aerial operations costs. A computer program based on this algorithm and on the models has been used experimentally with success in the O.C.P. area of West Africa. Such a tool is promising both for cost reduction and treatment efficacy in large control programs, while minimizing environmental impact. The models can also be useful for planning medium or small scale programs.

FACTORS INFLUENCING CAPTURES OF AUSTROSIMULIUM

BANCROFTI (TAYLOR) (DIPTERA: SIMULIIDAE) BY SILHOUETTE TRAPS IN EASTERN AUSTRALIA. J.W.O. Ballard, Department of Entomology, University of Queensland, St. Lucia, Australia, 4067.

Three silhouette traps of novel design were used to investigate trap location by the taxon *A. bancrofti* at three widely separated sites. The CO₂-baited traps were of different shape but similar in all other respects. Recordings of environmental variables were averaged over hourly intervals for each day and each distance between traps and linked to corresponding hourly trap counts. Different variables influenced trap captures at the three sites and were included in models which generated fitted estimates of flies captured under defined conditions. Temperature, relative humidity and wind speed were important variables at each site. There was a significant effect of trap shape at two sites. Highest numbers of flies were captured in the elongate trap at Ipswich, and in the square trap at Taylors Arm. Near Canberra there was no effect of trap shape on numbers captured. The importance of these results in understanding the behaviour of the taxon is discussed.

ACTIVITY OF 3 AUSTROSIMULIUM SPECIES IN SOUTH WESTLAND, NEW ZEALAND (DIPTERA: SIMULIIDAE). T.K. Crosby, Entomology Division, DSIR, Private Bag, Auckland, New Zealand.

The attraction and biting activity of the simuliids *Austrosimulium unguatum*, *A. dumbletoni*, and *A. australense* towards moulting Fiordland crested penguins (*Eudyptes pachyrhynchus*) was studied for a 6 day period in February 1977 at Jackson Bay, South Westland. It was part of a study of the role of simuliids in transmitting the haemosporidian *Leucocytozoon tawaki* to penguins.

Overcast conditions attracted more simuliids to penguins than clear conditions, and cold or hot air temperatures attracted fewer simuliids than mild temperatures. Both *A. unguatum* and *A. dumbletoni* had peaks of attraction and biting in the morning and evening, whereas *A. australense* only had a morning peak.

The percent composition of the simuliid species attracted to the penguins averaged 82% *A. unguatum*, 13% *A. dumbletoni*, and 5% *A. australense*. However, certain penguins attracted a markedly larger or smaller percentage of *A. dumbletoni* or *A. australense* than others. The percentage of simuliids which bloodfed depended upon the individual penguin they were attracted to, and this percentage did not vary greatly between each of the simuliid species attracted to a particular individual.

COMPARISON OF DIFFERENT PYRETHROIDES TO PREVENT BLACK FLY (DIPTERA: SIMULIIDAE) ATTACK AND SIMULIOTOXICOSIS IN CATTLE. A. Liebisch and A. Ziemer, Institute of Parasitology, Department of Veterinary Entomology, Tierärztliche Hochschule, D-3000 Hannover, F.R. Germany.

Comparative field studies were performed in 2 endemic areas in Germany where black flies (*Odagmia ornata*, *Boophtera erythrocephala*) usually cause heavy damage and mortality in livestock. Cyfluthrin, cyhalothrin, cypermethrin, deltamethrin and permethrin were applied by spraying and topically as pour-ons. Spraying gave better results than pour-on application but pour-on followed by additional wipe-on treatment of the less hairy parts was very effective. No case of simuliotoxicosis, neither death nor disease, occurred in the treated animals. However, 10 animals died after black fly attack in the same area when they were left without treatment, and other cattle were treated symptomatically. Permethrin spraying (3mg/kg) prevented 67% of black flies from taking a blood meal for 7 days. Cyhalothrin (5mg/kg) and Cypermethrin (5mg/kg) reduced black fly attack for 83% during 2 days after spraying.

PERMETHRIN RESIDUES IN HAIR AND TISSUE OF CATTLE EXPOSED TO SELF-TREATMENT BACKRUBBERS. H.G. Philip*, M.J. Herbut, Y. Kumar, Alberta Environmental Centre, Vegreville, Alberta, Canada T0B 4L0, and H.E. Braun, Ontario Ministry of Agriculture & Food, Guelph, Ontario, Canada N1G 2W1.

Free-choice and forced-use backrubbers were evaluated for the application of 0.5% permethrin to 2 groups of free-ranging beef cattle for protection from the northern black fly, *Simulium arcticum* Mall. Average daily dosage of permethrin/animal for the free-choice and forced-use treated cattle was 0.08 g and 0.30 g, respectively. Permethrin was found over the entire body of all treated cattle. Highest hair residues were found on the head, back, and flanks. After 5 and 12 weeks of treatment, hair residues had increased on the average and were greater on forced-use treated cattle (155.9 and 223.0 µg/g hair) than on free-choice treated cattle (9.83 and 20.26 µg/g hair). Tongue, blood, muscle, kidney, liver, omental and perirenal fat samples were analyzed for permethrin (detection limit 0.002 ppm). Residues were detected only in the fat tissues (<0.1 ppm) from forced-use treated cattle 1 and 2 weeks after treatment ceased.

CATASTROPHIC DRIFT OF BLACK FLY (SIMULIIDAE) LARVAE: COMPROMISE IN *BACILLUS THURINGIENSIS* H-14 EFFICACY. M.M. Galloway* and D.K. Burton, Canada Biting Fly Centre, University of Manitoba, Winnipeg, Canada R3T 2N2.

Catastrophic drift of black fly larvae resulting from either the injection of *Bacillus thuringiensis* H-14 (de Barjac), *Bti*, or from manipulation of river discharge occasionally resulted in inadequate reductions of larval abundance. In evaluations of *Bti* as a black fly control agent under a variety of conditions in prairie rivers, reductions of 90% or more in larval populations of several species of *Simulium* were usually achieved over distances of up to 15 km. Catastrophic drift of 14- to 20-fold pre-exposure levels was estimated at sites 200 and 250 meters downstream of application. A 7-fold increase in larval abundance of 7 km downstream observed in one evaluation of a 1 minute dosage is attributed to survival of drifting larvae exposed to a dosage attenuated by travel downstream. A similar increase did not occur in a comparison treatment of a 15 min dosage. Failures of *Bti* treatment occurred 4 to 6 days following rapid and major fluctuations of river discharge, and is attributed to disruption of larval populations initiated prior to *Bti* application.

THE MECHANICAL TRANSMISSION OF RETROVIRUSES. L. D. Foil* and C. J. Issel. Departments of Entomology and Veterinary Science, Louisiana State University Agricultural Center, Baton Rouge, LA 70803.

The mechanical transmission of equine infectious anemia virus (EIAV) by insects is generally accepted as a major factor in the transmission of the virus. The majority of the studies on EIAV transmission by insects have been to demonstrate that the phenomenon can occur under laboratory conditions using acutely infected, febrile donors with viremia of CA 10^6 infectious doses per ml (ID/ml). Our studies have been oriented toward describing the factors that contribute to the probability of transmission in nature, considering that viremia in infected horses can range from 1 (inapparent) to 10^6 (febrile) ID/ml. We will present data from: 1. a 7-year study of the tabanid populations associated with a band of inapparently infected mares pastured with negative sentinels; a comparison of years with epizootics to years with no transmission; 2. ELISA techniques for measuring the amount of blood residue on the mouthparts of tabanids following an interrupted blood meal. Furthermore, results of recent mechanical transmission trials of bovine leukemia virus will be presented. A perspective on the implication of the above studies for the transmission of human retroviruses will be presented.

CORRELATION BETWEEN VIRAL ISOLATIONS AND THE LOCATION OF A BOVINE PERSISTENTLY INFECTED WITH BLUETONGUE VIRUS. F.R. Holbrook*, L.H. Thompson and R.J. Bobian, USDA, Agricultural Research Service, Arthropod-borne Animal Diseases Research Laboratory, P.O. Box 3965, Laramie, Wyoming, USA 82071.

Bluetongue virus (BTV) is carried in most of the USA by the biting midge, *Culicoides variipennis*. From 1981-83 in a study area in eastern Colorado, polyacrylamide gel electrophoresis (PAGE) examinations of BTV serotype 11 isolates from bovines or insect vectors revealed an electropherotype with a double-banded pattern at 5 of 10 polypeptide segments. In 1984, similar examinations revealed an intrusion of a single-banded electropherotype. By 1985, all new infections were of this same single-banded type. From 1982-85, annual isolates of BTV-11 from one female bovine in the study area were identical and double-banded. With the concomitant shift to the single-banded type in the surrounding area, these isolations indicated a persistently-infected animal. During 1985, 20 BTV-11 isolations were made from *C. variipennis* in the study area. Six of these isolates were taken from the same premise and all were homologous with isolates from the persistently infected bovine. The other 16 insect-source isolates were of the single-banded type.

OCTENOL, AN EFFECTIVE TRAP ATTRACTANT FOR TABANIDAE (DIPTERA), F.E. French*, D.W. Long, Department of Biology, Georgia Southern College, Statesboro, Georgia, USA 30460, and D.L. Kline, Insects Affecting Man and Animals Research Laboratory ARS-USDA, Gainesville, Florida, USA 32604.

Octenol was tested in paired, 6-meter Malaise/flight traps (with a central baffle 4.5 m long) and in paired canopy traps (1.5 m² base). Both trap types had glossy, black rectangular and spherical targets. 1-octen-3-ol was evaporated from wicks inside the traps (less than 0.05 ml/hour). Canopy traps with octenol caught more individual tabanids, $P < 0.001$, than traps without octenol. Canopy traps baited with dry ice and octenol caught more tabanid individuals and taxa than traps with dry ice alone, $P < 0.05$. *Tabanus molestus* Say comprised 70% of the tabanids collected in the canopy traps (in July). Malaise/flight traps with octenol collected more individuals but no more taxa than traps without, $P = 0.05$; the dominate species (October) were *Tabanus sulcifrons* Macquart (39%) and *T. gladiator* Stone (31%). Octenol increased the total number of tabanids collected by about three-fold in both trap types.

STUDIES ON DELTAMETHRIN IN THE CONTROL OF PERI-WILD PHLEBOTOMUS CHINENSIS (DIPTERA: PHLEBOTOMIDAE). Xiong Guang-hua and Jin Chang-fa, Department of Vector Biology and Control, Institute of Parasitic Diseases, CAPM, 207 Rui Jin 2 Rd., Shanghai 200025, P.R. China.

Phlebotomus chinensis in the loess plateau of north Shaanxi is exophilic and autogenic. They live in field caves. Residual spraying with deltamethrin to control *P. chinensis* was applied to field caves and villages in Yunyan Town of Yichuan county in 1985-1986. The dosage used was 25 mg/m in field caves and livestock caves and 12.5 mg/m in villages. In 1985, after spraying, sandfly density decreased to very low levels until the end of the sandfly season. However, it remained high in unsprayed field caves throughout the sandfly season. In 1986, after spraying, the sandfly densities were markedly decreased as compared with the same months in the previous year. In June in the unsprayed area, the sandfly density decreased by 79.1% in field caves and 71.5% in livestock caves of villages. In August, the sandfly density decreased by 46.9% in the field caves and 59.6% in village areas. The results show that the residual potency effect of deltamethrin was long enough to suppress sandfly numbers throughout the sandfly season (3.5 to 4 months). Deltamethrin spraying (25 mg/m) in field caves and livestock caves before or at the beginning of sandfly season, was effective and practical in the control of peri-wild *P. chinensis* in the loess plateau of northern Shaanxi.

SUSCEPTIBILITY OF PHLEBOTOMUS PAPATASI (DIPTERA - PSYCHODIDAE) TO INSECTICIDES IN ISLAMIC REPUBLIC OF IRAN. , M.A. Seyed Rashti, H.Yezdan Panah and M.Jedari., Department of Medical Entomology and Vector Control, School of Public Health and Institute of Public Health Research, Teheran University of Medical Sciences, P.P.Box 6446-14155 Teheran, Iran.

In Iran *Ph.papatasi* is widely distributed and it is the main vector of zoonotic cutaneous leishmaniasis. DDT has been applied as an adulticide for 15-20 years, and subsequently, dieldrin, malathion and later baygon were used on the southern slopes and foothills of the Zagros range.

Susceptibility tests were performed on *Ph.papatasi* in different parts of Iran, Isfahan, Khuzistan and Mash-had, during 1969 and 1985-1986. The base line value of LC 50 for DDT was 0.47%, being performed in the unsprayed area of Mash-had in northeastern Iran, in August 1969. In our recent studies *Ph.papatasi* was tested against DDT and dieldrin. These tests carried out in 1985-1986 showed, in spite of almost 5-15 years of DDT and dieldrin application in different areas *Ph. papatasi* remained susceptible to these insecticides.

PHYTOPHAGY OF KENYAN PHLEBOTOMINE SANDFLIES. J. B. Kaddu*, M. J. Mutinga and R. M. Musyoki, International Centre of Insect Physiology and Ecology (ICIPE) PO Box 30772, Nairobi, Kenya.

The diet of sandflies is likely to affect the development of *Leishmania*, the causative agent of Leishmaniasis, in the vector and hence influence disease transmission and distribution. Plant-feeding of sandflies *Phlebotomus papatasi* was reported in the Middle East by Schlein *et al.* (1986 *J. Med. Entomol.* 23, 11-15). We hereby report the phytophagy of Kenyan sandflies *Sergentomyia schwetzi* and *Sergentomyia ingrami*. Caged male and female laboratory-reared *S. schwetzi* and *S. ingrami* were offered 44 plant species belonging to 21 families for 16 hours at 25±1°C and 90% rh. The sandflies were then dissected and tested for sugars using anthrone test (Van Handel, 1972 *Mosq. News* 32: 458; Young *et al.* 1980 *Trans. R. Soc. Trop. Med Hyg.* 74: 363-366). The observed preferences of sandfly species and sexes for different plant species, determined by percentage feeding rates, is discussed.

POPULATION FLUCTUATIONS OF PHLEBOTOMID SAND FLIES (DIPTERA: PHLEBOTOMIDAE) IN BIRBHUM (WEST BENGAL), INDIA. Somnath Banerjee, Department of Zoology, Suri Vidyasagar College, Birbham, West Bengal, India.

Assessment of populations of phlebotomid sand flies is important in the surveillance as well as the control of kalazar. Bi-monthly surveys were undertaken for two consecutive years to study the numerical fluctuations of *Phlebotomus argentipes* Annandale and Brunetti, and *Phlebotomus papatasi* Scopoli from six localities in Suri, Birbhum district, West Bengal, India where kalazar cases were documented. Altogether 976 phlebotomid sand flies were collected with an aspirator tube per man hour from indoors. The maximum population was recorded in the months of July and August (the monsoon months). The incidence of sand flies was low during winter months (November to January). The population fluctuations are discussed in relation to atmospheric temperature and humidity.

TOXICOLOGICAL INVESTIGATIONS OF THE FAILURE OF PYRETHROIDS TO CONTROL THE SHEEP BODY LOUSE, *DAMALINIA OVIS* (SCHRANK) (PHTHIRAPTERA: TRICHOECTIDAE). G.W. Levot and P.B. Hughes*, Department of Agriculture, New South Wales, P.M.B. 10, Rydalmere, N.S.W. 2116, Australia.

Pour-on formulations of synthetic pyrethroids have been used to eradicate *D. ovis* on sheep in Australia since 1981. By 1986 resistance was suspected as a reason for control failures. A laboratory bioassay was developed in which lice were exposed for 16 hours on insecticide-impregnated cotton gauze. Considerable variation in response to the pyrethroids was evident, with a 10x difference in LC₅₀ between the most susceptible strain and the more resistant ones which had survived several pyrethroid treatments in the field. There was no apparent cross-resistance to the organophosphate diazinon. Regular use of pour-on treatments has probably selected the most resistant individuals within populations. When these individuals predominate, it is sufficient to form detectable infestations of lice on sheep soon after treatment. The emergence of this resistance has stimulated a reappraisal of methods for lice control which will be discussed in terms of the traditional attitudes to the problem of lice on sheep in Australia.

SEX PHEROMONE IN THE TICK *ORNITHODOROS SAVIGNYI* (ACARI: ARGASIDAE). G.M. Khalil*, A.S. Marzouk, M.A. Roshdy and F.S.A. Mohamed, Department of Zoology, Faculty of Science, Qatar University, Doha, Qatar.

Bioassays performed on *O. Savignyi* demonstrated the presence of a female sex pheromone. Unfed adults and fed adults, after various postfeeding periods, were cross-tested. Two independent criteria were used, the percentage of positive male responses and the time elapsed before these responses. Females were least attractive when unfed and on the feeding day. Their attractiveness increased afterwards reaching the highest values 6 days postfeeding (most attractive, MA, females) then decreased gradually thereafter. Males were least responsive during the first 2 postfeeding days and became more responsive afterwards reaching a peak 8 days postfeeding (sexually active, SA, males). Unfed male responses to MA females were strong but were lower than those of SA males. The fastest responses in all bioassays were those of SA males to MA females. The maximum range of SA male response to MA females was ca 9 cm. SA males were not attracted to nymphs, MA females with sealed coxal orifice or MA dead females. However, they responded to nymphs coated with coxal fluid collected from MA females.

COMPLEX MULTICOMPONENT PHEROMONE SYSTEMS REGULATING MATE RECOGNITION AND SPECIES DISCRIMINATION IN IXODID TICKS. D.E. Sonenshine*, S.A. Allan, J.G.C. Hamilton, D. Taylor, J.S. Phillips and R.M. Silverstein. Department of Biological Sciences, Old Dominion University, Norfolk, Virginia, USA 23529 and Department of Chemistry, College of Environmental Sciences and Forestry, State University of New York, Syracuse, New York, USA 13210.

Mate recognition in ixodid ticks is regulated by sex pheromones. In most metastriate species, feeding females secrete 2,6-dichlorophenol to attract males. In many species, females also secrete a mounting sex pheromone (MSP) which enables males to recognize them as mates and search for the genital pore. Differences in the MSP deter most intergeneric matings but these differences are less effective in deterring interspecific encounters. In *Dermacentor variabilis* and *D. andersoni*, males identify conspecific females when they recognize the species-specific genital sex pheromones (GSP) in the genital pore. A mixture of C14-C18 free fatty acids in the vaginal tract and on the external ventral body surface serves as a component of the GSP in these species. Natural differences in fatty acid concentration in *D. variabilis* and *D. andersoni* may be one of the factors facilitating mate recognition at the species level. The role of GSP in other genera, is being studied. The identity of the MSP is unknown.

HOST RESISTANCE TO THE HUMAN BODY LOUSE (*PEDICULUS HUMANUS*) INDUCED BY IMMUNIZATION WITH LOUSE EXTRACTS. D. Ben-Yakir* and Y.K. Mumcuoglu, Department of Parasitology Hebrew University - Hadassah Medical School, P.O.B. 1172, Jerusalem 91010, Israel.

The possibility of inducing host resistance to lice by immunization with louse tissue extracts was investigated. A laboratory colony of the human body louse, adapted to feed on rabbits, was used. Test rabbits were immunized with an extract of a homogenate of either the whole body or the midgut tissue of the louse; controls, with either ovalbumin or saline. Test rabbits developed high titers of anti-louse antibodies. A group starting with 500 lice, including all active stages, was reared for 2 weeks on each of the rabbits. Lice that fed on the immunized rabbits took significantly smaller blood meals than those on control rabbits. The rate of development and fecundity were lower and mortality was higher in lice reared on the test rabbits. Lice reared on rabbits immunized with midgut extract suffered a greater damage and many of them died as a result of a ruptured gut.

The immuno-blotting technique was used to identify immunogenic proteins in louse extracts, using sera from test rabbits.

HOST ASSOCIATIONS AND SEASONAL ACTIVITY OF TICK VECTORS OF CRIMEAN-CONGO HEMORRHAGIC FEVER VIRUS IN SENEGAL. Mark L. Wilson*, Jean-Louis Camicas, Jean-Paul Cornet. Institut Pasteur, B.P.220, Dakar, Senegal.

At least 28 species of Acari, mostly "hard" ticks, are able to support infection by Crimean-Congo Hemorrhagic Fever virus (CCHFV), a zoonotic disease agent that is focally enzootic throughout Africa and southern Eurasia. Both the virus and its potential vectors (*Hyalomma*, *Amblyomma*, and *Rhipicephalus* species) occur in western Africa. As part of a multifaceted project on the ecology and epizootiology of this human zoonosis, we analysed the host feeding patterns and seasonal activities of certain of these ticks. Domestic ungulates, small mammals, and birds were examined monthly and relative attachment rates were calculated. Questing tick activity was monitored by flagging. The quantitative importance of these hosts to tick population dynamics and maintenance of virus transmission was analysed. Results are evaluated in the context of intervention designed to decrease transmission and reduce the risk of human disease.

USE OF AQUATIC INSECTS IN DETERMINING SUBMERSION INTERVALS OF CORPSES. N.H. Haskell*, D. G. McShaffrey, and R.E. Williams, Department of Entomology, Purdue University, West Lafayette, Indiana 47907.

The use of aquatic insects in determining submersion intervals at death scene investigations has not been exploited in the past, although great potential exists. Aquatic environments have no true specific indicator species as do terrestrial habitats. However, aquatic environmental studies show that organisms may colonize a substrate dependent on factors such as, size, position, exposure to current, water temperature, current speed, water depth, the presence of algal communities, or detritus. Certain aquatic insects such as the chironomid midges (Diptera, Chironomidae), and the caddisflies (Trichoptera), are capable of colonizing emersed bodies; and with the known biology of a specific species of insect for a certain geographic area, time intervals of immersion can be established.

During preliminary examination of the body of a homicide victim found in central Indiana, a peculiar red "fiber" was noticed and recovered. Initially believing this to be a carpet fiber, the item was subjected to fiber analysis. It was found to be a short coiled particle not like any known natural or synthetic fabric fiber. Subsequent examinations determined this "fiber" to be the larva of a common fresh water midge, Chironomidae. It is very important that forensic pathologists and other forensic scientists consult with the entomologists to insure that vital crime scene evidence is recognized and properly identified, to gain the greatest potential from that evidence.

IXODID TICK-DERIVED ANTIGENS AS POSSIBLE INDUCERS OF HOST RESISTANCE. D. C. Jaworski*, G. R. Needham, Acarology Laboratory, Department of Entomology, and M. T. Muller, Department of Molecular Genetics, The Ohio State University, Columbus, Ohio, U. S. A., 43210.

Ixodid tick salivary glands secrete substances which can induce host resistance to tick feeding. Host resistance is expressed in reduced numbers of ticks feeding, reduced female engorgement weights and reduced reproductive capacity. Salivary gland antigens of *Amblyomma americanum* (L.) females from the first 3 days of attachment were characterized by immune sera from resistant or hyperimmune sheep and rabbits. Feeding-specific antigens at 58, 45 and 43 kilodaltons were detected with antibody probes raised to 3-day fed salivary glands, however, antibody probes to unfed glands did not recognize these antigens. Clearly, sheep and rabbit hosts produce antibodies in response to specific tick salivary gland polypeptides; and these polypeptides may play a role in protective immunity against successful tick feeding. Further investigation into the immunogenicity of specific salivary gland antigens is underway through the use of recombinant DNA techniques.

RESISTANCE TO IXODID TICKS (*DERMACENTOR VARIABILIS*) IN MAST CELL-DEFICIENT MICE. E.B. Steeves* & J.R. Allen, Department of Veterinary Microbiology, University of Saskatchewan, Saskatoon, Canada. S7N 0W0.

Tick resistance in guinea pigs has been shown some time ago to be associated with cutaneous basophil reactions in which the basophils apparently play key roles in disrupting the normal bloodfeeding behavior of the ticks.

In our laboratory it has also been shown that BALB/c and C3H strains of mice acquire resistance following infestations with *Dermacentor variabilis* larvae. In the original work, histopathological studies revealed elevated numbers of mast cells, eosinophils and neutrophils in the skin of challenged resistant mice, and it was suggested that the mast cells in these mice might perform key roles in the mechanism of tick resistance. However, it was found that mast cell-deficient (W/W^v) mice also readily acquired resistance, so mast cells are presumably not essential to the murine resistance mechanism.

Skin biopsies from W/W^v mice undergoing repeated tick infestations have been studied in detail. Three-micron sections of methacrylate-embedded tissue stained with a modified Wrights-Giemsa procedure, and ultra-thin sections of Epon-embedded tissue have revealed the presence of cells resembling basophils in sites close to tick attachments in the skin of resistant mice. (Murine basophils are said by many to be non-existent, and are not revealed by standard histological procedures).

IMMUNOGENIC PROPERTIES IN RABBITS AND IMMUNOHISTOCHEMICAL LOCALISATION OF A 25 kDa PROTEIN OF *IXODES RICINUS* (ACARI: IXODIDAE). B. Rutti*, T. Haug, L. Bovet and M. Brossard, Institute of Zoology, University of Neuchâtel, Switzerland.

The importance of a 25 kDa protein (25 kDa) in the acquisition of resistance has been investigated by immunoblotting with serum of pluriinfested rabbits. More than 50% of the rabbits developed antibodies against this protein. Ticks fed on these animals had a substantially lower mean weight. The immunostimulation of rabbits occurred from the beginning of tick feeding and anti-25kDa antibodies were already detectable after the 1st infestation. To confirm the ability of the 25 kDa to induce resistance, rabbits were inoculated with a fraction containing mainly this protein. Less ticks were able to attach on such immunised animals, and those able to feed, took a smaller blood meal as compared to those on naive animals. Employing the immunofluorescence and protein-A-gold technique the 25 kDa has been localised by light and electron-microscopy in the epidermis of the alloscutum and in some types of fat-body cells of female ticks fed between 2 and 5 days on rabbits. The 25kDa has been detected in vesicles of both cell types using either specific anti-25 kDa polyclonal antibodies or sera of pluriinfested rabbits. Further experiments are in progress to evaluate the role of the 25 kDa during expansion of the alloscutum in Ixodid ticks.

STUDIES ON THE ULTRASTRUCTURE OF TICK FOVEAL GLANDS AND THE SEX PHEROMONE RELEASED BY THEM WITH X-RAY MICROANALYSIS. Jiang Zai-jie* and Li Ying, Department of Biology, Beijing Normal University, Beijing, China 100088.

The structure of foveae and foveal glands of 6 species of ixodid ticks were studied with scanning and transmission electron microscope, and the differences among different species, and different sex or different stages of the same species were analysed. After feeding the size of female foveal gland is increased, the lobes of gland are expanded, in their cytoplasm many secretory granules are contained. All of that are related with the secretion of sex pheromone. The relationships between the release of sex pheromone and feeding or mating of ticks were studied. The effective component of sex pheromone released by foveal glands via the foveae is 2,6-dichlorophenol (DCP). Due to the DCP contains chlorine (Cl), the changes of its content of the foveae, measured by X-ray microanalysis (X-RAM), indicates the secretory activity of foveal glands. In feeding process the content of Cl is increased. After feeding 1-2 days it shows a distinct increase over that of unfed female. After feeding 3-5 days the content of Cl reaches the highest. After mating it is decreased, approached to that of unfed female. The results obtained with X-RAM are identical with the results of biological assay completely.

REGULATION MECHANISM OF VITELLOGENIN INDUCTION AND OVARIAN DEVELOPMENT BY ENGORGEMENT IN ADULT FEMALES OF *ORNITHODOROS MOUBATA* (ACARI: ARGASIDAE). Y. Chinzei, Department of Medical Zoology, School of Medicine, Mie University, Edobashi, Tsu, Japan 514.

Engorgement and mating have been thought to be prerequisites for the induction of vitellogenesis in ticks. But we found that sublethal doses of a pyrethroid, cypermethrin (CyM), which is a neuroactive insecticide, can induce vitellogenin synthesis and complete oocyte maturation in unfed unmated adult females of *O. moubata*. We got some evidences from the ligation and implantation experiments that CyM stimulates the synganglion (SyG) to release factor which induces vitellogenesis. It was also suggested by ligation experiments that this factor is conserved in SyG of unfed adult females and released enough for stimulation of vitellogenesis during the feeding for about 40 min after coxal fluid secretion. We found an activity for vitellogenesis induction in the crude extract of SyG from unfed unmated adult females. This activity was heat-unstable and sensitive to proteolytic enzymes. These results suggested that peptide hormone may be one of the important factor(s) for inducing vitellogenesis in this species and that this peptide is secreted from SyG if it is stimulated by engorgement and mating, and also by any factor(s) other than engorgement (ex. CyM) even before feeding.

A COMPARISON OF METHODS FOR ESTIMATING POPULATION DENSITY OF *IXODES DAMMINI* (ACARI: IXODIDAE) IN A LYME DISEASE FOCUS. D. Fish*, T.J. Daniels, Medical Entomology Laboratory, Dept. of Medicine, New York Medical College, Valhalla, New York, USA 10595, and R. C. Falco, Westchester County Department of Health, Bureau of Disease Control, White Plains, New York, USA 10601.

Three methods were evaluated for their accuracy in estimating the density of nymphal *Ixodes dammini* in an endemic focus of Lyme disease in southern New York State, USA. Tick traps baited with dry ice recruited *I. dammini* only over short distances and their accuracy in estimating population density is highly dependent upon trap placement. Population estimates from the abundance of ticks on animal hosts was found to be influenced by both host abundance and host catchability. The drag cloth method was found to be the most accurate of the 3 methods evaluated because it samples a relatively constant proportion of the questing tick population.

TICK CEMENT SUBSTANCE: ITS ROLE IN THE CATTLE TICK BOOPHILUS MICROPLUS AND ITS ABSENCE IN THE AUSTRALIAN PARALYSIS TICK IXODES HOLOCYCLUS. Bernard F. Stone* and Keith C. Binnington*, CSIRO, *Division of Tropical Animal Production, Long Pocket Laboratories, Private Bag 3, Post Office, Indooroopilly, Queensland 4068, Australia; and *CSIRO, Division of Entomology, GPO Box 1700, Canberra City, A.C.T. 2601, Australia.

Most ticks secrete cement substance to assist in their attachment to their hosts. An exception to this is the Australian paralysis tick Ixodes holocyclus. In a comparative study with the cattle tick Boophilus microplus which is vitally dependant on this "holdfast" mechanism, the biosynthesis, secretion, structure and composition of cement from the latter was examined. These aspects will be discussed in relation to the role of cement and whether its absence in the paralyzing tick I. holocyclus is of any significance.

STUDIES ON TICKS OF VETERINARY IMPORTANCE IN NIGERIA XX. EFFECT OF PHOTOPERIOD ON THE OVIPOSITION PATTERN OF ENGORGED TICKS UNDER LABORATORY AND NATURAL CONDITIONS.

O.O. Dipeolu, A.O.J. Amoo* and O.A. Akinboade
Department of Veterinary Microbiology and Parasitology,
University of Ibadan, Ibadan, Nigeria.

The oviposition pattern of engorged Amblyomma variegatum, Boophilus decoloratus, Boophilus geigy and Hyalomma truncatum under artificial and natural photoperiods was studied. Oviposition started during the scotophase in all the experimental ticks except in those placed in continuous light. A. variegatum and Boophilus species kept in the other photoperiods exhibited ovipositional rhythm characterized by higher peaks during the scotophase, while engorged H. truncatum failed to oviposit. Ticks kept under other artificial and natural photoperiods exhibited ovipositional rhythm peculiar to their species. While it was concluded that light indirectly inhibits oviposition, high temperature tends to decrease or eliminate the inhibitory effect of light in Boophilus and Hyalomma species.

COMPARISON OF ESTERASE ISOZYME PATTERNS DURING THE DEVELOPMENTAL STAGES OF *ANOPHELES (CELLIA) VAGUS* AND *ANOPHELES (ANOPHELES) NIGERRIMUS*. H.M. Revanasiddalah, Department of Sericulture, Central College, P.K. Block, Bangalore University, Bangalore-560 009, India.

Genetic and developmental analysis of isozymes by the application of electrophoretic techniques is a new approach to the problems of systematics and evolution of mosquitoes. Esterase isozymes have been used as markers to elucidate mainly the developmental events in *Anopheles vagus* and *A. nigerrimus*. The developmental esterases have been classified into two categories. One category of esterases, which persists throughout the developmental stages, is made up of generalized, segregating and non-specific esterases involved in general metabolic functions such as the breakdown of lipids and fatty acids. The other category, confined to some of the developmental stages, is made up of non-segregating, specific esterases involved in modifying the hormones responsible for subsequent metamorphic events such as growth, moulting, pupation and differentiation. The esterase isozyme patterns observed during the different developmental stages, including adults, of *A. vagus* (which belong to the subgenus *Celia*) are quite different from *A. nigerrimus* (which belong to the subgenus *Anopheles*). Thus, based on isozyme patterns, these two species can be distinguished from each other and also from other Oriental anopheline species by the use of electrophoretic techniques.

DNA PROBES FOR SPECIES IDENTIFICATION OF MOSQUITOES IN THE *ANOPHELES GAMBIAE* COMPLEX. J.M. Crampton* and K.R. Gale, Wolfson Molecular Genetics Unit, Department of Medical Entomology, Liverpool School of Tropical Medicine, Pembroke Place, Liverpool L3 5QA, UK.

Identification of species within the *Anopheles gambiae* Giles species complex is essential for the correct evaluation of malaria vector ecology studies and control programmes. The development of DNA probes to distinguish species of the *An. gambiae* complex is described.

Genomic libraries were prepared for five members of the *An. gambiae* complex. These were screened using radiolabelled DNA from different species of *An. gambiae sensu lato* and a number of clones selected on the basis of their species specificity.

When used as hybridisation probes in a dot-blot assay, these sequences provide a sensitive means for the identification of 5 of the 6 species within the *An. gambiae* complex. A simplified protocol for the use of DNA probes will be presented which may be used to identify fresh, dried and alcohol preserved specimens. The future development and application of these probes for use in the field will be discussed.

DNA TRANSFORMATION IN THE MOSQUITO *AEDES AEGYPTI*. P. Eggleston*, J.M. Crampton, G.J. Lycett and A.C. Morris, Wolfson Molecular Genetics Unit, Department of Medical Entomology, Liverpool School of Tropical Medicine, Pembroke Place, Liverpool L3 5QA, England.

Transposable genetic elements show great potential for the manipulation of genomes. In particular, the P element has been widely used as a transformation vector among species of *Drosophila*. There is now considerable interest in the application of these techniques to organisms of major medical and commercial importance. Here, we describe their development in the mosquito *Aedes aegypti*, the major urban vector of filariasis, yellow fever and dengue fever. Techniques for the direct introduction of a P element transformation vector will be presented. This vector (pUC hs neo) carries a dominant selectable marker which allows transformants to be readily identified. Injection survival rates are comparable to those found in *Drosophila* and the nature of a number of integration events will be described. This vector has also been used to transfect cultured *Aedes aegypti* MOS 20 cells and evidence for both transient and stable transformation will be presented. Finally, the relationship between these integration events and transposition of the P element vector will be described.

TRANSPOSABLE GENETIC ELEMENTS AND GENOME ORGANIZATION IN *AEDES AEGYPTI*. A.M. Warren* and J.M. Crampton, Wolfson Unit of Molecular Genetics, Department of Medical Entomology, Liverpool School of Tropical Medicine, Pembroke Place, Liverpool L3 5QA, U.K.

Insect vector control programs may benefit from a greater understanding of the organism at the molecular level. Here, we present evidence for the existence of indigenous transposable genetic elements in *A. aegypti*, the major urban vector of yellow fever, dengue and dengue haemorrhagic fever.

Elucidation of *A. aegypti* genome organization has been essential for the isolation and cloning of these elements and will be discussed. Characterization of several clones has indicated that they exhibit properties similar to those observed in retroviruses. Such viruses have been successful in genetic manipulation of a number of organisms. Indigenous retroviral like elements (retrotransposons) may prove useful tools for the manipulation of the mosquito genome, thereby enhancing existing control programs.

MOLECULAR CHARACTERISATION OF ESTERASES INVOLVED IN INSECTICIDE RESISTANCE IN *CULEX QUINQUEFASCIATUS*. A.T. Merryweather*, J.M. Crampton, and H. Townson, Wolfson Unit of Molecular Genetics, Department of Medical Entomology, Liverpool School of Tropical Medicine, Pembroke Place, Liverpool L3 5QA, U.K.

Organophosphate resistance in Culicine mosquitoes is a major problem in their control and in the eradication of Bancroftian filariasis and arbovirus infections. Elevated levels of carboxylesterase activity have been observed to be associated with organophosphate resistance, and the esterases involved in *C. quinquefasciatus* are being characterised at the molecular level. A 60-65 kD peptide is present in resistant strains at a higher level than susceptible strains, and is associated with esterase activity. Rabbit antisera raised against the native esterase recognise this ~60 kD peptide, and effect its immunoprecipitation from *in vitro* translation products of *C. quinquefasciatus* mRNA.

The cloning and characterisation of the gene coding for this esterase will be discussed in relation to the analysis of insecticide resistance.

CULTURE, FORMULATION AND USE OF *LAGENIDIUM GIGANTEUM* FUNGUS FOR MOSQUITO CONTROL. R.C. Axtell, Department of Entomology, North Carolina State University, Raleigh, North Carolina 27695-7613, USA.

Optimal methods for culturing *Lagenidium giganteum* on sunflower seed extract are described. Storage and formulation of the asexual phase in alginate beads is described. Control of mosquito larvae with the fungus encapsulated in alginate or grown on agar plates with sunflower seed extract is dependent upon water quality and temperature. The relationships of fungal epizootics to larval densities and habitat conditions are presented. Under suitable conditions the fungus was shown to persist and control *Culex* mosquitoes for an entire season (5 months) following a single application.

VECTOR CONTROL IN INDONESIA: A COMMUNITY APPROACH. Sustriayu Nalim, Vector Control Research Unit, Selagia, Indonesia.

Local government officials, farmers, and agricultural and public health staff collaborated in developing an integrated control program in central Java where vector resistance to pesticides is developing. The basis of the program is fish culture: of the commercially valuable *Cyprinus carpio* and the larvivorous *Poecilia reticulata*.

After 5 years the SPR rate of malaria had decreased from 16.49% to 0.2%, densities of the vector *Anopheles aconitus* had decreased from 3.35/m²/day to 0.01, and farmers' income from fish culture had increased by Rp 133,750 (approx. U.S. \$84) per ha. As a result, this program is being increasingly widely adopted. Regular supervision by agricultural extension workers is essential for success.

MOSQUITO SPECIES (DIPTERA: CULICIDAE) SEASONAL ABUNDANCE IN THE DANUBE INUNDATION AREA OF VOJVODINA (YU).

D. Petrić*, M. Zgomba and Ž. Srdić, Institute for Plant Protection, University of Novi Sad.

The abundance and frequency of mosquitoes was investigated in detail by means of human bait catches and CO₂ baited CDC light trap catches, during March - October of three consecutive years.

On man *Aedes vexans* Meigen was consistently the most numerous species except in May when *Aedes sticticus* Meigen could be more numerous. In CO₂ baited CDC traps species composition was quite different with *Culex pipiens* complex mosquitoes being the most numerous during the summer months.

Coefficients of similarity showed that July and August were the most similar months for both trap and man and trap catches when night and day catches were compared. However it was noticed that the CDC trap was more efficient at catching *Ae. sticticus* during the night.

EFFECTS OF DIMILIN AND ATABRON ON THE DEVELOPMENT, FECUNDITY AND CUTICULAR STRUCTURE OF *Aedes albopictus* SKUSE (DIPTERA: CULICIDAE). C.M. Ho*, S.T. Tu, Y.C. Sung and J.Y. Wu, Department of Parasitology, National Yang Ming Medical College, and Department of Biology, Fu-Jen University, R.O.C.

Benzoylphenyl ureas have been known as a group of potent larvicides by interfering the molting process of many insects. The effects of dimilin and atabron on the development, fecundity and cuticular structure have been tested with the larvae of *Aedes albopictus*. The ED 50 of dimilin and atabron for the 4th-instar larva was 39.8 ppb and 67 ppb respectively. Late 4th-instar larva was more susceptible than those of early and middle stage. Neither reduction in fecundity nor reproductive system damage has been found in the adult survivors by treating the 4th-instar larva with 10 ppb of atabron. The 3rd-instar larvae were treated with 1 ppb of dimilin or atabron for 24 hours, strong inhibition for adult emergence was only found in dimilin treated group. The effect of atabron or dimilin on the cuticle structure of the larva survivors has been examined by transmission electron microscopy. The obscure laminae in the endocuticle and delay of apolysis was also only found in dimilin treated group.

OBSERVATIONS OF THE ECOLOGY OF SURVIVAL *ANOPHELES (CELLIA) MINIMUS* FORMS A & B IN HAINAN ISLAND (DIPTERA: CULICIDAE). Y. Yu* and Fan Bang-rong, Department of Vector Biology & Control, Institute of Parasitic Diseases, C&PM, Shanghai 200025, P.R. China

Based on morphological studies in 1981-1982, it was proved that *Anopheles (Cellia) minimus* might be divided two forms i. e. *An. (Cel.) minimus* forms A & B in Hainan Island. The present paper reports on the two forms of *An. (Cel.) minimus*, using the method for man- and cattle-baited huts, collected from Shil-liu area. During the course of survey (April-June 1986), 208 of *An. (Cel.) minimus* were collected from the window traps and inside of man-cattle-baited huts. 9.13% of the mosquitoes were *An. (Cel.) minimus* form A and 90.8% were of *An. (Cel.) minimus* form B. Precipitin test, showed 57.65% of 170 gorged female mosquitoes of *An. (Cel.) minimus* form B fed on cattle; 0.59% fed on man; 12.94% fed on both man and cattle; and 28.82% were negative.

PROPOXURE SUSCEPTIBILITY TEST OF *ANOPHELES STEPHENSI* LISTON IN SOUTHERN ISLAMIC REPUBLIC

OF IRAN (1976 - 1986). A.V. Manouchehri and M.R. Yaghoobi - Ershadi, School of Public Health, Teheran University, P.O. Box 6446 - 14155, Teheran, Iran.

Anopheles stephensi the main vector of malaria in southern Iran is resistant to D.D.T, dieldrin and malathion. Susceptibility tests carried out with propoxure impregnated papers during 1976 - 86 in 5 villages in Minab county, showed that, inspite of 10 years propoxure application 2 times per year in dwellings, *Anopheles stephensi* remained susceptible to this insecticide.

STUDIES ON THE CHARACTERISTICS OF THE LARVAL BREEDING SITES OF THE MOSQUITOES IN THE DISTRICTS OF MINAB, HORMOZGAN PROVINCE, IRAN (1985-86). M.R. Yaghoobi-Ershadi*, M. Zaim and A.V. Manouchehri, School of Public Health, Teheran University, P.O.Box 6446-14155, Tehran, Iran.

With regards to the importance of using biological methods and sanitation in the control of mosquitoes and the mosquito-transmitted disease, a comprehensive study on the ecological characteristics of the breeding sites were carried out in the districts of Minab during 1985-86. In this program a total of 6500 4th instar mosquito larvae from 217 breeding sites in 12 districts of Minab, representing 20 species in 5 genera were collected. Seven species belonged to the subfamily Anophelinae and the remainder to the subfamily Culicinae. This study showed 15 kinds of breeding sites in the districts of Minab. Seven types of them were of natural breeding sites and the remainder were artificial ones. The characteristics of the breeding sites of every species and their local distribution in the districts of the area have discussed separately in the paper.

INDOOR RESTING MOSQUITOES IN PHNOM PENH, KAMPUCHEA. M. Kohn⁺, P. Kohnová, Institute of Parasitology, Czechoslovak Academy of Sciences, České Budějovice, Czechoslovakia

Indoor resting mosquitoes (M) were collected in Phnom Penh at various periods. 7 localities were observed in the area of the town, altogether 250 houses. M were collected during 8 minutes in every house by means of the aspirator and the net. Total of 15 species of M resting in houses was found, one of them for the first time in Kampuchea's area.

Culex quinquefasciatus is the dominating species in 6 localities observed. Its dominance in houses is more or less evident; *Aedes aegypti* is the dominating species in 1 locality. Percentage of dominance *Ae. aegypti* in houses is corresponding with the risk of the occurrence of Dengue haemorrhagic fever. *Anopheles vagus* was found resting in higher abundance in houses of one locality. This fact is of little epidemiological significance because of zoophilic character of *A. vagus* in Kampuchea. On the other hand even uncommon occurrence of *Anopheles subpictus* found in houses may signalize a possibility of endemic occurrence of malaria in Phnom Penh.

STUDIES ON THE MOSQUITOES (DIPTERA: CULICIDAE) OF THE MANGROVE AREAS IN THE NORTH WESTERN PENINSULAR MALAYSIA. Abu Hassan Ahmad* and Salmah M. Rawi, School of Biological Sciences, Universiti Sains Malaysia, 11800 Pulau Pinang, Malaysia.

A general survey of adult and immature stages of mosquito was carried out in and around the mangrove areas North Western Peninsular Malaysia. The main species of mosquito found on the fringe of the mangrove swamps were *Mansonia indiana* Edwards and *Culex sitiens* Wiedemann where as *Aedes* sp. and *Uranotaenia lateralis* Ludlow were common inside the mangrove swamps proper.

Seasonal abundance, biting activity and parity of females of *Mn. indiana*, *Cx. sitiens* and *Aedes* sp. mosquitoes were studied. Factors relating to the above phenomena, such as, rainfall, moonlight, wind and tide were correlated. Night catches were done at the fringe of the mangrove swamps and day catches were carried out in the mangrove swamps.

Resting adult populations of *Aedes* sp. and *Ur. lateralis* were sampled from tree holes and crab holes respectively. These results indicated a relationship between tides (spring and neap) and abundance of the mosquitoes.

ANTENNAL OLFACTORY RESPONSES IN TSETSE FLIES (*GLOSSINA* SPP.): EFFECT OF SEX, STARVATION AND AGE. C.J. Den Otter, Department of Animal Physiology, University of Groningen, The Netherlands.

Electroantennogram (EAG) recordings revealed that in *G. morsitans* and *G. tachinoides*, the olfactory sensitivity of the males is higher than that of the females, whereas in *G. austeni* and *G. f. fuscipes* the females are more sensitive than the males. In the former two species, the olfactory sensitivity increases with increasing starvation, whereas in *G. austeni* and *G. f. fuscipes*, the EAG responses remain about the same up to 4-6 days hunger.

Experiments with repleted male and female *G. morsitans*, 1, 5, 10, 15, 20 and 30 days old, showed that the responses to 1-octen-3-ol, 3-nonanone and 4-heptanone decrease with increasing age. However, the sensitivity of the antennae to acetone hardly changes during this period of time.

It could be concluded from cross-adaptation experiments that 3-nonanone and 4-heptanone stimulate the same type of receptor cell in the antennae, whereas two additional types of cells exist which are sensitive to 1-octen-3-ol and acetone, respectively.

STUDIES ON THE MALE ACCESSORY GLAND PROTEINS OF TSETSE FLIES (*GLOSSINA* SPECIES) (DIPTERA: GLOSSINIDAE).

R.A. Balogun, Department of Zoology, Obafemi Awolowo University (Formerly University of Ife), Ile-Ife, Nigeria.

The male accessory reproductive gland proteins of four *Glossina* species namely, *G. m. morsitans*, *G. m. centralis*, *G. m. submorsitans* and *G. palpalis palpalis* were studied using gel electrophoresis and high pressure liquid chromatography. Differences were observed in the electrophoretic and high pressure liquid chromatographic protein patterns of the four species. The patterns revealed that the species differed with regard to the occurrence of some protein bands and the relative concentrations of others. The results thus suggest that the male accessory gland products in *Glossina* could be species-specific.

BIOLOGY OF *CUTEREBRA AUSTENI* SABROSKY IN THE SOUTHWESTERN UNITED STATES (DIPTERA: CUTEREBRIDAE). C.R. Baird, Southwest Idaho Research and Extension Center, University of Idaho, Parma, Idaho, USA, 83660.

Cuterebra austeni, a recently described bot fly parasite of *Neotoma* woodrats, is known from Arizona, California, Colorado, New Mexico, and Mexico. Adults emerge in March and are active at hilltop aggregation sites in southern Arizona into late spring. Mature third instar larvae are found in woodrat hosts from late May to August.

AGGREGATION AND MATING BEHAVIOR OF THE REINDEER WARBLE FLY, *HYPODERMA TARANDI* L. J.R. Anderson*, A.C. Nilssen, and I. Folstad, Department of Entomology, University of California, Berkeley, USA 94720, and Institute of Ecology, University of Tromsø, 9000 Tromsø, Norway.

Hypoderma tarandi L. is a holarctic parasite of caribou and reindeer that causes considerable damage to its host. As mature larvae drop out of their migratory hosts the resulting pupae/adults are widely dispersed over vast areas. Studies in arctic Norway indicate that *H. tarandi* has evolved a dual mating strategy that overcomes the problem of widely-dispersed males and females. Both sexes meet and mate at two types of distinctly recognizable landmarks. On the expansive, treeless tundra biome mating sites are unique, widely separated rocky areas located along one or both sides of small streams. On lower wooded hillsides and valleys flies mate at certain topographical sites along dirt road tracks/pathways. The latter sites resemble prominent, well-worn trails used during seasonal migrations. Reproductive success in this short-lived species appears dependent on continued emergence throughout the summer, enabling at least some individuals to successfully mate and seek hosts on the few good days for fly activity each year.

AGENTS FOR BIOLOGICAL CONTROL OF NOVEL HOSTS: ASSESSING *ALEOCHARA* SP. (COLEOPTERA: STAPHYLINIDAE), A PARASITOID OF DIPTERA. E.J. Wright, CSIRO Division of Entomology, G.P.O. Box 1700, Canberra, A.C.T. 2601, Australia.

In some biological control programs natural enemies must be sought from hosts other than the target species, leading to uncertainties of establishment and control. CSIRO has been investigating natural enemies of *Haematobia thirouxii* potans (Bezzi) (Muscidae) in southern Africa for use against *H. irritans exigua* De Meijere in northern Australia.

A method of evaluating host specificity was developed for a common, undescribed, southern African *Aleochara* sp., as a aid to choosing species for introduction. Studies involved laboratory tests of acceptance and subsequent development in species from common families of dung-breeding flies, alone or in combination with *H. thirouxii* potans. Success of parasitization varied with host species, from no penetration of the host puparium, to penetration but no feeding, to complete development to adult. While there were species effects, host mass alone was a good predictor of preference for attack, parasitoid survival and adult parasitoid size. Based on its puparial mass, pupation site and taxonomic affinities, *H. irritans exigua* in Australia is likely to be a suitable host for *Aleochara* sp.

ADVANCES IN THE CONTROL OF PUBLIC HEALTH INSECTS BY THE APPLICATION OF WATER BASED ULTRA LOW VOLUME SPACE SPRAYS. J.M. Groome, R. Martin and R. Slatter*, Technical Development Department, Wellcome Research Laboratories, Berkhamsted, Herts, U.K. HP4 2DY.

Controlling insects by space spraying insecticidal formulations from vehicle mounted spraying machines has proved to be a very effective method of rapidly reducing insect pest populations. Insecticide formulations have traditionally been applied either undiluted or diluted with hydrocarbon solvents such as diesel. With the ever increasing awareness of environmental contamination by such solvents, the use of water as a diluent is to be favoured. Unfortunately the rapid evaporation of water produces sprays where the droplets are too small to impact efficiently on the target insects. This paper reports field work carried out to evaluate the performance of a water based formulation where the evaporation of water from the spray droplets has been significantly reduced.

An excellent level of control of houseflies (*Musca domestica* L.) was achieved.

GENETIC CONTROL AND RECOVERY OF A POPULATION OF *LUCILIA CUPRINA*. R.J. Mahon and G.G. Foster, CSIRO Division of Entomology, GPO Box 1700, Canberra Australia 2601.

The myiasis blowfly *L. cuprina* is a serious pest of sheep, costing the Australian wool and sheep-meat industry approximately \$A150 million annually. During a trial to test the efficacy of a field-female killing system based on sex-linked translocations, male *L. cuprina* carrying a Y-autosome translocation and the recessive lethals white eye, rusty body, featherless arista and topaz eye in repulsion to the translocation elements, were introduced on a 4,000 hectare island carrying 6,000 sheep. An average of 1.35 million males were released weekly between August 1985 to May 1986. Towards the end of the release period, the genetic death rate imposed on the native population reached 88% and the population had declined to barely detectable levels. Recovery of the population to levels where strike would be a problem was slow as a result of the residual genetic load and because of the intervention of a period of unfavourable weather conditions during the summer. The persistence of suppressive effects in generations not exposed to released males is an important component of the genetic system.

CONTROL OF SUMMER MASTITIS WITH USE OF INSECTICIDAL EAR-TAGS. K.-M. Vagn-Jensen * and J.B. Jespersen, Danish Pest Infestation Laboratory, Skovbrynet 14, DK-2800 Lyngby, Denmark.

The paper will discuss the possibility of controlling the fly-transmitted cattle disease summer mastitis with insecticidal ear-tags in Denmark. The sheep head fly *Hydrotaea irritans* (Fall.) is assumed to be the main transmitter of summer mastitis, an acute destructive polybacterial infection of the udder in non-lactating pasturing heifers and dry cows.

The capability of several different insecticidal ear-tags to control *H. irritans* is discussed as well as the possible reflection of the fly control on the number of infected heifers. The discussion is based on investigations made in Denmark in the grazing seasons 1983 to 1986, involving several thousand heads of Black and White Dairy Cattle (or Frisian). The heifers were tagged with different types of ear-tags and compared with similar groups of untreated heifers grazing in comparable pastures. The reduction in numbers of *H. irritans* due to tagging was investigated in selected localities, by comparing the number of flies on treated and untreated cattle, once a week.

INDIVIDUAL FLY LOAD AND DIFFERENTIAL RISK IN CONTRACTING SUMMER MASTITIS IN HEIFERS: INTRA-SPECIFIC KAIROMONE VARIATION AS A CAUSAL FACTOR. G. Thomas*, H.J. Prijs and J.J. Trapman, Dept. of Parasitology, Central Veterinary Institute, Lelystad, The Netherlands.

Summer mastitis is an acute, suppurative, multibacterial mastitis which occurs in calves, heifers and non-lactating cows during the summer months when animals are at pasture. Transmission of the disease takes place through an insect vector — *Hydrotaea irritans* (Diptera: Muscidae). The risk in contracting the disease is not equal for all individuals. One of the causes underlying this differential in risk will certainly involve the resistance of the individual to infection. In summer mastitis, however, where the disease is spread by an insect vector another factor will play a role. Relative differences between hosts in their attractiveness for vectors will lead to higher fly pestation loads and could thus increase probability of transmission. Evidence is presented to support this. Analysis of relative differences in attractiveness to flies revealed that these remain stable not only within season but also between seasons. Asking the question why some individuals are more attractive to flies than others is tantamount to determining the stimulus set used by the fly in selecting its host. A causal study aimed at identifying the relevant stimuli revealed that host odour signals play a primary role. As these are functional in interspecific communication and, moreover, may result in deleterious consequences on the fitness of the individual producing them, they can be classified as kairomones. In summary, differential risk between heifers in contracting summer mastitis is at least partly due to intra-specific variability in kairomone.

FILTH FLIES AND THEIR POTENTIAL NATURAL ENEMIES IN POULTRY PRODUCTION SYSTEMS IN THE PHILIPPINES. L.M. Rueda*, C.T. Hugo, and M.B. Zipagan, Department of Entomology, University of the Philippines at Los Banos, College, Laguna 4031, Philippines.

An extensive survey of house fly and other filth flies, and their arthropod predators and parasites associated with broiler and caged-layer poultry production facilities was conducted in selected areas of the Philippines. About 11 species of common filth flies (Diptera) belonging to 8 genera and 4 families (i.e. Muscidae, Calliphoridae, Sarcophagidae and Stratiomyidae) were collected and identified. Concerning natural enemies, about 8 species of parasitic Hymenoptera, belonging to 6 genera and 3 families (i.e. Pteromalidae, Chalcididae and Diapriidae) were found attacking pupae of *Musca domestica* Linn. and other filth flies. About 35 species of arthropod predators and scavengers, classified under 14 families and 6 orders were recovered. The seasonal and relative abundance of the common parasites and predators in poultry farms was determined. The rates of parasitism and predation of common natural enemies also were evaluated.

THE STUDY ON CERTAIN BIOLOGICAL CHARACTERS OF *NASONIA VITRIPENNIS* WALKER (HYMENOPTERA: PTEROMALIDAE). W.Z. Zhang* and K.D. Liang, Department of Parasitology, Shanxi Medical College, Taiyuan, Shanxi, China.

Certain biological characters of *Nasonia vitripennis* were investigated under natural room temperature. The parasitism ratio of 4 kinds of fly pupae parasitized by this wasp were: *Musca domestica* L. 85%, *Lucilia sericata* Mg. 92%, *Aldrichina grahami* Aldr. 76% and *Bercaea haemorrhoidalis* Fall. 14%. The parasitism ratio were higher while parasite-host ratio is 1:2.5 and 1:5. The 1 and 2-day-old pupae were suitable to be parasitized by this wasp. The longest longevity could reach 17 days and the shortest be 5 days. The mortal time 50% and 90% of this wasp were 11 and 15 days. The average daily survival was 85%. The number of average total progeny produced by a female adult wasp in her lifespan was 473 and the sex-ratio was 4 female to 1 male. The threshold for development was 11.8°C and the thermal constant was 177 day degree. 6-9 generations were produced per year in the area of Taiyuan. The problems about mass culturing and release of this wasp were discussed.

HABITAT ASSOCIATIONS OF HYMENOPTERAN PARASITOIDS OF HOUSE FLY PUPAE AT DAIRIES IN NEW YORK STATE. L. Smith* and D. A. Rutz, Department of Entomology, Comstock Hall, Cornell University, Ithaca, NY 14853.

Eight species of hymenopteran parasitoids are commonly found attacking house fly pupae in central New York. These species are ectophagous, and most of them have a broad host range. Thus, interspecific competition may have resulted in habitat specialization by some of the species. Surveys using sentinel bags of house fly pupae placed in different microhabitats at dairy farms indicate that some species have specific habitat associations whereas others do not. It may be important to consider such associations when choosing which species to release for biological control at a particular site.

EFFECT OF DIETS AND LARVAL DENSITY ON OVARIAN DEVELOPMENT OF ADULT MUSCID FLIES, MUSCA BEZZII AND MUSCA HERVEI. K. Kuramochi*, M. Iwasa, K. Shimokawa and K. Hori, Laboratory of Entomology, Obihiro University of Agriculture and Veterinary Medicine, Obihiro, Hokkaido 080, Japan.

In Japan, two species of muscid flies, M. bezzii and M. hervei are important external parasites of grazing cattle. The ovaries of adult of both species normally developed by rearing on proteinous diets in the laboratory. When the adults were fed with only sugar and water (protein-free) after emergence, terminal follicle(s) in the ovariole(s) completely developed in all of M. bezzii and 40% of M. hervei. Namely these species were autogenous. From the results of laboratory experiments, cow blood and dung were effective proteinaceous materials for ovarian development of both species, however, tear, snivel and saliva secreted from cattle did not promote the ovarian development of M. bezzii adult. These results were different from those of M. autumnalis, whose biology is very similar to those of above two species. In both species, imaginal ovary slowly grew and the rate of autogeny reduced as the larval density increased.

ATTRACTION OF MOSQUITOES TO THREE IMPORTANT SPECIES OF BIRDS IN OAK HAMMOCK MARSH, IN MANITOBA. G. Fortney* and R.A. Brust, Department of Entomology, University of Manitoba, Winnipeg, Manitoba, Canada R3T 2N2.

The present Oak Hammock Marsh Wildlife Management Area represents a remnant of what was once Manitoba's largest prairie marsh, and provides habitat for many types of fauna, including large numbers of waterfowl during the migration periods. Bird-baited mosquito traps were set out in the marsh to determine which species are attracted to birds that inhabit the marsh. Mosquitoes breeding in and around the marsh were attracted to caged mallard ducks and to caged yellow-headed black birds, the two most common avian hosts in the marsh. Caged blackbirds were more attractive to *Culex tarsalis*, the primary vector of Western Equine Encephalitis, than ducks and domestic chickens. Overall, ducks attracted 39% of the female mosquitoes (total of 16 species) while 37 and 21% were attracted to blackbirds and chickens respectively. A significant percentage took blood meals from their bird hosts.

MOSQUITOES AND VECTORS OF DISEASES IN THE KINGDOM OF BRUNEI. Shivaji Ramalingam, (Formerly), Department of Parasitology, University of Malaya, Kuala Lumpur, Malaysia.

Brunei lies on the northern part of the island of Borneo, wedged between the Malaysian states of Sabah and Sarawak. The total land area is only 2,226 square miles, three-fourths of which is covered with tropical rain forests. Knowledge of the mosquito fauna was entirely lacking, although the following mosquito borne diseases occur there: malaria, filariasis, dengue, dengue haemorrhagic fever and Japanese encephalitis.

A mosquito survey extending for 3 weeks during June-July, resulted in 306 collections made in 31 localities. Over 5,300 mounted and labelled adults were obtained and nearly 2,850 permanent slides of whole larvae and associated skins were prepared. A total of 96 species of mosquitoes in 14 genera were identified and these include 28 new records from Borneo. Numerous stages that were previously unknown, were also obtained. The peculiarities and affinities of the mosquito fauna will be discussed as well as the vectors and potential vectors of diseases.

MOSQUITO-BORNE ARBOVIRUSES IN SOUTHEASTERN AUSTRALIA. R.C. Russell, Medical Entomology Unit, ICPMR, Westmead Hospital, NSW, 2145, Australia.

In the summer of 1973-74 a major outbreak of Australian encephalitis, caused by the Flavivirus Murray Valley Encephalitis (MVE) and Kunjin (KUN), began in the southeast of Australia and within 6 months human infections were reported from all mainland States. Although human infections with MVE have occurred only in northern areas of Australia since 1974, KUN has been recorded more recently in the southeast and the Alphavirus Ross River virus has become recognised by public health authorities to be of considerable concern as a cause of morbidity in the southeast of Australia.

Data on antibody prevalence as evidence of human infection with arboviruses has been gathered and the southeastern States of New South Wales, Victoria and South Australia have instituted seasonal programmes to monitor virus and vector activity. Mosquito control is conducted routinely in some areas, and research is undertaken into aspects of the natural history of some arboviruses, of vector biology and of vector control.

ALPHAVIRUS-VECTOR INTERACTIONS: RAPID DISSEMINATION AND CYTOPATHOLOGY. T.W. Scott*, S.C. Weaver, and L.H. Lorenz, Department of Entomology, University of Maryland, College Park, Maryland 20742, USA.

We are studying the interaction between eastern equine encephalomyelitis (EEE) virus and its mosquito vector (*Culiseta melanura*) to determine the rapidity of alpha-virus transmission by mosquitoes and the effect of virus infection on the arthropod host. Orally infected mosquitoes have been examined using the fluorescent antibody technique, organ titration in cell culture, light microscopy, and transmission electron microscopy. EEE virus disseminates from the mosquito's midgut via hemolymph and is released into salivary matrix within 48 hours. Mosquitoes can transmit virus to chicks in 48-72 hours. During the early stages of infection virus is most easily detected in posterior midgut epithelial cells and muscle associated with the gut and reproductive tract; later fat body and salivary glands are infected. Nervous tissue seldom contains detectable virus. During the 2nd-5th days of infection, cytopathological alterations occur in the posterior midgut epithelial cells. Heavily infected cells are sloughed into the gut lumen or degenerate within the epithelium. In some specimens the midgut basal lamina is disrupted. These results will be compared with reports of other alphavirus-mosquito interactions.

PASSAGE OF HOST IMMUNOGLOBULIN G FROM BLOODMEAL INTO HEMOLYMPH OF SELECTED MOSQUITO SPECIES. J.A. Vaughan* and A.F. Azad, Department of Microbiology & Immunology, University of Maryland School of Medicine, Baltimore, Maryland, USA 21201.

The passage of ingested host antibody (IgG) from the digestive tract into the hemolymph was examined in 6 species of mosquitoes. Mosquitoes were fed upon either an immune bloodsource (i.e., typhus-immune rat) or nonimmune bloodsource (control rat). At selected intervals post-ingestion (p.i.), hemolymph samples and midgut contents were collected and assayed for rat IgG using indirect immunofluorescent assay techniques. Within 3 hrs. p.i., antibody appeared in the hemolymph of *Anopheles stephensi*, *An. gambiae*, and *An. albimanus*. Host antibody persisted longer in the gut of these species (24 - 48 hrs. p.i.) than in the hemolymph (18 - 24 hrs. p.i.), suggesting that the passage of antibody occurred early on in the digestion process but then was halted at some point. Host antibody was detected at very low levels in the hemolymph of *Culex pipiens* at 3 hrs. p.i. but not thereafter. Antibody passage did not occur in *An. freeborni* and *Aedes aegypti*. The species which exhibited marked antibody passage stayed on the host and fed for extended periods of time while simultaneously excreting red fluid from the anus. This rectal fluid contained intact erythrocytes and host IgG. Mosquito species not displaying antibody passage fed relatively quickly, left the host and did not exhibit such "prediuretic" activity while feeding.

EFFECTS OF HOST ANTI-MOSQUITO ANTIBODIES ON MOSQUITO PHYSIOLOGY. Manthri S. Ramasamy, Queensland Institute of Medical Research, Brisbane, 4006, Queensland, Australia.

The possibility that antibodies ingested with the bloodmeal and directed against mosquito components may interfere with the physiology of the mosquito was investigated. Results show that rabbit antibodies against head/thorax, midgut and abdomen tissues of bloodfed mosquitoes reduce the fecundity of *Aedes aegypti*. By immunofluorescence techniques antibodies have been shown to cross the gut and be localised in oocytes. However, monoclonal and polyclonal antibodies against purified vitellin do not effect fecundity, indicating that other target antigens are involved. The possible effects of anti-mosquito antibodies on infection and transmission of pathogens is also being investigated and the results will be discussed with reference to the control of human disease.

AN OVIPOSITION SITE SELECTION PHEROMONE OF LARVAL ORIGIN IN *AEDES TRISERIATUS* (DIPTERA: CULICIDAE). A. MAIRE* and D. N'Dry, Département de Chimie-Biologie, Université du Québec à Trois-Rivières, C.P.500, Trois-Rivières, Qc, Canada G9A 5H7.

The oviposition preference of *A. triseriatus* females for waters containing larvae of mosquitoes was already demonstrated. However this attraction was not attributed with evidence to the larvae themselves. An experimentation was performed using axenic larval rearing waters. Results indicated the production of an oviposition inducing pheromone by the larvae. This not volatile substance is produced by the larvae as soon as their hatching. There is evidence of a density-dependence like effect at high larval density. *A. triseriatus* females show a specificity for larvae of their own species when offered the choice between *A. triseriatus* and *A. atropalpus* larval holding waters. This result infirmed previously published data, opening the way to promising interpretation on the oviposition site selection mechanisms from an evolutive point of view.

EFFECTS OF SUCROSE AND JUVENILE HORMONE ON EGG DEVELOPMENT AND MORTALITY IN STARVED *AEDES AEGYPTI* MOSQUITOES. M.J. Klowden, Division of Entomology, University of Idaho, Moscow, Idaho 83843 USA.

Few female mosquitoes starved since emergence will develop eggs after a small blood meal. However, by supplementing the blood meal with sucrose either before or immediately after the blood, the percentage that undergo egg maturation can be significantly increased. If it is fed later than 12 hr after blood ingestion, the sucrose is no longer able to supplement the blood. Juvenile hormone or methoprene administered after the blood meal can also significantly increase the percentage of otherwise starved females that develop eggs, but both also cause high mortality.

PURIFICATION AND CHARACTERIZATION OF MOSQUITO OOSTATIC HORMONE. D. Borovsky*, IFAS - University of Florida, Florida Medical Entomology Laboratory, Vero-Beach, FL 32962 and D. A. Carlson, USDA SEA AR IAMARL, Gainesville, FL 32604, USA.

The existence of antigonadotropins or oostatic hormones that inhibit egg development has been demonstrated in the cockroach, eye gnat, crustaceans, house fly and mosquitoes. Several mechanisms of inhibition have been suggested to explain the inhibitory effect of these hormones. Mosquito oostatic hormone has been purified from the ovaries of *Ae. aegypti* using low and high pressure liquid chromatography. The hormone is a small polypeptide of M_r 2,200. Injection of the hormone into female *Ae. aegypti* inhibited egg development, proteolytic enzyme activity, and blood digestion in the midgut. Oostatic hormone given by enema, on the other hand did not inhibit proteolytic enzyme activity, indicating that the hormone acts outside the gut. Injection of oostatic hormone into decapitated and ovariectomized females that did not synthesize ecdysteroids inhibited trypsinlike enzyme synthesis and blood digestion in the midgut, indicating that oostatic hormone inhibits the midgut cells and not the ovary or the brains endocrine system. The hormone is not species specific and a direct relation between hormone synthesis and regulation of trypsinlike activity in the midgut is proposed. USDA 12394

Anopheles quadrimaculatus (Diptera: Culicidae) Dispersal Studies: Techniques and Equipment. A. A. Weathersbee, III and M. V. Meisch*. Department of Entomology, University of Arkansas, Fayetteville, AR 72701.

Studies were initiated to determine the dispersal rate of the adult malaria mosquito, *Anopheles quadrimaculatus*, in Arkansas ricelands. An economical, portable resting unit was designed to recapture marked mosquitoes at numerous radial distances from a centralized release point. The unit was quite effective and recovered marked mosquitoes at maximum distances of 1.7 and 2.6 mi after one and two nights of dispersal, respectively.

DIFFERENTIAL TOLERANCES OF FORAGING AND RESTING MOSQUITOES TO REPELLENTS. L.C. Rutledge and N.M. Echano. Letterman Army Institute of Research, Presidio of San Francisco, California, USA 94129-6800.

Ten repellents (deet, dimethyl phthalate, dibutyl phthalate, MCK Repellent 11, MCK Repellent 326, ethyl hexanediol, Citronyl, butoxypolypropylene glycol, butoxyronoxyl, and permethrin) were tested against *Aedes taeniorhynchus* (Wiedemann) and *Aedes aegypti* (Linnaeus) by an in vitro blood-feeding test method and by a World Health Organization (WHO) test method for determining the irritability of mosquitoes to contact insecticides. The responses of foraging *Ae. taeniorhynchus* and *Ae. aegypti* to the test materials were significantly correlated (blood-feeding test method), but the responses of resting *Ae. taeniorhynchus* and *Ae. aegypti* to the test materials were not significantly correlated (WHO test method). Responses in the blood-feeding test system were not significantly correlated with those in the WHO test system in either species.

It was concluded that foraging and resting mosquitoes of the same species respond differently to repellents. Foraging mosquitoes of different species respond similarly to repellents, but resting mosquitoes of different species respond differently to repellents.

INVESTIGATION OF TUNING AND RESONANCE IN THE ANTENNAE OF MOSQUITOES EXPOSED TO SOUNDS. P. Belton, Centre for Pest Management, Biological Sciences, Simon Fraser University, Burnaby, British Columbia, Canada, V5A 1S6

Sound waves at the lower end of the audible spectrum vibrate the flagella of antennae of both male and female mosquitoes. Using frequencies sweeping from 80 to 640Hz, the mechanical vibrations of the flagellum and the electrical activity of chordotonal sensillae in Johnston's organ were measured simultaneously. The antennae of four species examined respond to air movement and are increasingly sensitive to sounds of lower frequency if the sound pressure is held constant. The antennae of female *Aedes aegypti* are more sensitive to sounds than those of males but are not as sharply tuned to a particular frequency. Differences and similarities in the mechanical and electrical responses between the sexes and species is illustrated and discussed.

ALBERTA CATTLE GRUB CONTROL PROGRAM 1968-88 TOWARDS ERADICATION OF HYPODERMA SPECIES. B.A. Khan and S.R. Gould, Animal Industry Division, Alberta Agriculture, Edmonton, Alberta, Canada. T6H 5T6.

Twenty years of organized campaign against cattle grubs *HYPODERMA LINEATUM* (deVill) and *HYPODERMA BOVIS* (L) in the province of Alberta, resulted in drop in infestation from 44% to 1.5%. Legislative and extension methods were responsible for the success of the program. The key players in the success of the program are the municipal governments, packing industry, feedlot operators, cattle markets and cattle producers of Alberta. Alberta cattle grub control program consists of 66 projects related to extension enforcement and financial management. Alberta Department of Agriculture under the pest control act provides legal, financial and technical assistance to project managers. Integration of above management techniques is unique in North American pest management programs.

The history of cattle grub control program in Alberta coincide with the history and development of systemic insecticides, which also played a key role in the control of cattle grubs.

BEHAVIORAL AND NEUROPHYSIOLOGICAL EVIDENCE FOR THE MODE OF ACTION OF THE INSECT REPELLENT, DEET, AGAINST THE MOSQUITO, *Aedes aegypti* L. (DIPTERA: CULICIDAE). E.E. Davis, Vector Biology Program, SRI International, Menlo Park, California 94025 USA.

An important means of protecting ourselves against blood-sucking arthropods and the diseases that they transmit when other means of control are either ineffective or impractical is through the use of topically applied chemical insect repellents such as N,N-diethyl-m-toluamide (deet). Unfortunately, the search for newer and better repellents has failed to produce any such substances for our use. Probably the most significant reason for this failure is that we know neither the site nor mode of action of these substances. Previously, we have suggested several possible mechanisms for how insect repellents might work. Here I report the results of an integrated study of how the insect repellent, deet, modifies both the behavior of individual females flown in a wind tunnel and the activity of the antennal chemoreceptor for the host attractant, lactic acid, in a manner that suggests a possible mode of action for deet in female *Aedes aegypti* mosquitoes.

EXPERIMENTAL BEDDING SYSTEMS FOR CONTROL OF LARVAL HOUSE FLIES AND STABLE FLIES IN OUTDOOR CALF HUTCHES.

E. T. Schmidtmann* and R. W. Miller, ARS, USDA, Beltsville, Maryland 20705.

Experimental bedding systems were evaluated in replicated six-week field trials for control of larval (maggot) house flies, *Musca domestica* L., and stable flies, *Stomoxys calcitrans* (L.), in outdoor calf hutches. House fly (HF) and stable fly (SF) density in experimental hutches bedded with ground corncob, wood chips or sand, and with or without a hydraulic filter to enhance drainage, were compared with HF and SF density in straw bedding as a control. In wood chips or wood chips plus filter bedding, HF density averaged 9.0 and 10.5 and SF 16.0 and 20.0 maggots per sample, respectively, reductions of 63 to 76 percent. In ground corncob plus filter, HF and SF density averaged 11.3 and 3.6 (1/8"-size particles) or 1.5 and 1.1 (1/4"-size particle) maggots per sample, reductions of 68 to 97 percent. Sand bedding suppressed HF density 91 percent ($\bar{x}$ = 2.5 maggots per sample) and SF 99 percent ($\bar{x}$ = 0.4 maggots per sample), but compacted and soiled with calf feces. These results indicate that alternative calf hutch bedding systems have potential as a new approach to regulating muscoid fly populations on dairy farms.

#43

BEHAVIORAL DIFFERENCES OF ADULT CHIRONOMID AND CULICID DIPTERA AS INDICATED BY THEIR ATTRACTION TO LIGHT. A. Ali*, University of Florida, IFAS, Central Florida Research and Education Center, 2700 East Celery Avenue, Sanford, FL 32771, USA.

Six New Jersey light traps were employed in the field to assess attractiveness of adult midges and mosquitoes to six incandescent light sources of different colors and wattages (intensities). White, yellow, orange, blue, green, and red lamps were used. White incandescent and fluorescent lamps were also compared. Glyptotendipes paripes Edwards, Goeldichironomus holoprasinus Goeldi, and Chironomus crassicaudatus Malloch midges preferred white over yellow, and both were preferred over red, orange, green, or blue. Light intensity was more important than color in attracting midges. In contrast, Aedes spp., Anopheles spp., Culex spp., and Psorophora spp. mosquitoes were, in general, more attracted to blue, even though of lowest intensity. Fluorescent light attracted significantly ($P=0.05$) more mosquitoes than incandescent white light, but midges were attracted equally to both the light sources.

#44

PREVALENCE OF DUST MITES IN THE HOMES OF ASTHMATICS IN SEVERAL U.S. GEOGRAPHICAL REGIONS. L.G. Arlian and D.L. Vyzzenski-Moher*, Department of Biological Sciences, Wright State University, Dayton, Ohio 45435.

The purpose of this study was to determine the prevalence of dust mites in the homes of mite sensitive asthmatics in order to evaluate the success of immunotherapy for mite induced asthma. Dust samples were obtained from 224 homes located in Cal., Fla., La., N.C., Ohio, Tenn., and Texas. Mites were present in 97-100% of homes in the various geographical areas. D. farinae (DF), D. pteronyssinus (DP), E. maynei (EM), and Blomia sp. were the most common mites but their prevalence varied geographically. Fifty-two to 98% of homes contained DF and 63-98% contained DP. Homes in Cincinnati, Memphis, Greenville, and Delray Beach contained predominantly DF while homes in New Orleans, Galveston, San Diego, and Los Angeles contained predominantly DP. Forty to 86% of all homes were coinhabited by DF and DP. EM was found in New Orleans, Memphis, Galveston, San Diego, and Delray Beach and in several homes this was the most prevalent species. During the summer months mites were more prevalent in bedroom carpets and family rooms than in mattresses but the number of homes where mattresses were the primary mite foci increased during the heating season. Average mite density was above 100 mites/g dust in most of the homes.

#45

STUDIES ON THE BIOLOGY OF THE HOG LOUSE (ANOPLURA: HAEMATOPINUS SUIS L.) FROM THE DOMESTIC PIG AND THE WILD BOAR. G. Beder, Untersuchungs-labor für Schädlinge, D- 3006 Burgwedel 4.

The nomenclature of the hog lice infesting domestic pigs (Sus scrofa domestica) and the wild boar of Europe (Sus scrofa) is confusing. It could be demonstrated by comparative morphological studies of lice from the domesticated host and from the wild host from different parts of the world that the length of heads and the width of the sternal plates are of different size in both sexes of adult lice of the two hosts.

The type and the location of the fixation of the nits differ in the two lice according to the different hair coat of the host. Biological studies on the host preference or specificity are going on.

The results support the opinion of Ferris (1933) that Haematopinus suis (Linnaeus) of the domestic pig and Haematopinus aperiis (Ferris) of the wild boar should be considered as two different species.

#46

PURIFICATION AND CHARACTERISATION OF ESTERASES RELEVANT TO ORGANOPHOSPHATE RESISTANCE IN ANOPHELES. R.G. Boddington,* and C.A. Malcolm, Department of Entomology, London School of Hygiene and Tropical Medicine, Keppel Street, London, WC1E 7HT.

Esterases, primarily from 1-day old adults, of malathion resistant and susceptible strains of Anopheles stephensi were investigated by polyacrylamide gel electrophoresis and purified using size exclusion liquid chromatography (LC) and anion exchange high performance LC. Malathion carboxylesterase, which is the established resistance mechanism in the resistant strain, was found to have a molecular weight of 50 000 and showed little or no hydrolysis of the non-specific esterase substrates used. Inhibition of non-specific esterase activity and radiolabelled insecticide metabolism studies revealed that two soluble esterases, in addition to malathion carboxylesterase, were capable of metabolising organophosphates at low levels *in vitro*, which if amplified, as is common among Culex and recently reported in Anopheles albimanus, could potentially confer resistance.

#47

STUDIES ON AMPLIFIED ESTERASE ELECTROMORPH VARIANTS IN ORGANOPHOSPHATE RESISTANT CULEX PIPIENS. A. Callaghan, Department of Medical Entomology, London School of Hygiene and Tropical Medicine, Keppel St., London, WC1E 7HT.

Studies were undertaken on esterases from a chlorpyrifos resistant strain of Culex pipiens from Italy. Polyacrylamide gel electrophoresis revealed several electromorph variants stemming from two gene loci, which were isolated by selective breeding over twenty generations. Six families were produced containing different combinations of seven electromorph variants, one of which has been recorded as amplified in other strains of organophosphate resistant Culex pipiens. Analysis of the variant families by means of insecticide bioassays revealed differences in survival of larvae over time. These qualitative differences were investigated by means of metabolic and kinetic studies. These results are being used to develop and/or improve current biochemical detection methods for esterase-mediated organophosphate resistance.

#48

SOME PHYSIOLOGICAL STUDIES ON CULEX THALASSIUS. W. A. Chinery, Ghana Medical School, Box 4236, Accra.

Studies on survival of the aquatic stages of Culex thalassius (collected from a coastal lagoon in Accra) in different concentrations of sea water, indicated that in 50% and 100% sea water, survival was significantly higher in larvae from the "sea water" end than in those from the "fresh water" end of the lagoon (viz $Z=7.07$, $p<0.01$ in 50% and $Z=7.55$, $p<0.01$ in 100% sea water). Larval survival was low in 150% and 200% sea water with little difference between survival rates of larvae from the two locations in the lagoon. In 50% and 100% sea water, emergence rates of adults from surviving larvae were significantly higher in larvae from the "sea water" end than in those from the "fresh water" end (viz $t=5.57$, $p<0.01$, in 50% and $t=5.96$, $p<0.01$ in 100% sea water). In 150% and 200% sea water, there was slight difference between low emergence rates of adults observed in surviving larvae from the two ends although emergence rates from pupae collected directly from the lagoon were much higher. Results of host preference experiments indicated that chicken and guinea-pig with higher feeding rates and fecundity were better hosts than mice while the rat was a poor host. The significance of these results in the laboratory maintenance of adults and mechanical control of the aquatic stages of this species is briefly discussed.

#49

THE FEMALE TABANIDS OF EASTERN MISSISSIPPI, USA (DIPTERA: TABANIDAE). R.L. Combs* and J. MacDonald, Department of Entomology, Mississippi State University, Mississippi State, MS, USA 39762.

A six year study of the tabanids from Eastern Mississippi has resulted in a collection of 35 species in six genera. Tabanids were collected from tethered steers, canopy traps and box traps. Daily and seasonal activity, preferred feeding site on host and speciation was studied. Six species account for 90% of the tabanids collected. The data will be shown by photographs, graphs and charts in a poster presentation.

#50

A SIMULATION MODEL OF SARCOPTIC MANGE IN SWINE. D. P. Davis and R. D. Moon, Department of Entomology, University of Minnesota, St. Paul, MN, 55108.

A simulation model was developed from values reported in the literature and current research results. The model simulates development of (i) mite populations, (ii) immunity, (iii) itching, (iv) crusted lesions, and (v) effects on average daily gain. Immune development is based on cumulative mite burden. Immunity increases mite mortality either directly via immunoglobulins or hypersensitive lesion development, or indirectly by causing itching. Development of crusts is a dynamic process. Crusts are refugia where mite mortality declines and populations increase exponentially. Data from experimental infestations are in general agreement with model predictions. Further evidence is needed regarding the dynamics of crusted lesion growth, effects of immune response on mite biology, and relationships between host responses and mites on average daily gain.

#51

ESSAI DE TRANSMISSION MECANIQUE DE *Trypanosoma vivax* ZIEMANN (KINETOPLASTIDA: TRYPANOSOMATIDAE) PAR LE TAON NEOTROPICAL *CRYPTOTYLUS UNICOLOR* (WIEDEMANN) (DIPTERA: TABANIDAE). S. Ferenc (College of Veterinary Medicine, University of Florida, Gainesville, FL 32601, USA), H.L. RAYMOND (INRA & Direction des Services vétérinaires, 97306 CAYENNE Cedex, Guyane française) et R. LANCELOT (IEMVT, 94704 MAISONS-ALFORT Cedex, France).

Un essai de transmission mécanique de *Trypanosoma vivax* a été réalisé en Guyane française, région où ce parasite est fréquent et où les taons sont abondants. *Cryptotylus unicolor* est un taon crépusculaire très commun, dont le comportement est très favorable à la transmission mécanique d'agents pathogènes par repas interrompu et à l'obtention de repas de sang interrompus en captivité. Plusieurs de ces taons ont été autorisés à se nourrir successivement sur un veau infecté par injection d'un stabilat de trypanosomes et sur un veau receveur sain. Une parasitémie est apparue chez le veau receveur deux semaines après le début des transferts d'insectes. Des essais complémentaires seraient nécessaires pour préciser l'importance de ce mode de transmission dans les conditions naturelles.

#52

STUDIES ON CULICOIDES HYPERSENSITIVITY "SWEET ITCH" IN LOUISIANA HORSES. C. S. Foil, L. D. Foil, R. E. Corstvet, C. Klimczak, M. Klass, and F. Enright. Department of Entomology and School of Veterinary Medicine, Louisiana State University, Baton Rouge, LA 70803.

Hypersensitivity to the feeding of various species of *Culicoides* is an important cause of seasonal pruritic dermatitis in adult horses. Aspects of the etiology of "sweet itch" or "Queensland itch" have been identified in Australia, England, Ireland, British Columbia, and Israel. Although this problem is considered important in the U.S., there have been no studies that identify the species of *Culicoides* that are feeding on symptomatic horses and demonstrate a response to skin testing using antigens prepared from these species. We will report the results of a 2 year study. The *Culicoides* populations on 4 farms were followed using CDC light traps with dry ice as a synergist. The feeding sites on horses for different species was determined by aspirating feeding *Culicoides* off the horses. We were fortunate in our study to collect 2 species of *Culicoides* that were feeding on horses and causing the behavior that contributes to the self-induced dermatitis of "sweet itch". We will also report the findings of skin tests with antigens prepared from wild-caught and colonized *Culicoides* in normal and allergic horses.

#53

THE EFFECT OF MATING ON HOST-SEEKING BEHAVIOR DURING OOCYTE MATURATION IN *AEDES AEGYPTI*. D.A. Haggart* and E.E. Davis, Vector Biology Program, SRI International, Menlo Park, California 94025.

There is a marked difference in the degree of inhibition of host-seeking behavior between inseminated and uninseminated female mosquitoes following a blood meal. In gravid uninseminated females, as compared to gravid inseminated ones, the inhibition of host-seeking behavior after the meal 1) has a slower onset, 2) is less pronounced, and 3) diminishes more rapidly. We observed that these differences in host-seeking behavior correlated with differences in the sensitivities of their lactic acid receptors. It has been reported that the fat body of blood-fed females produces a hemolymph-borne factor that depresses the sensitivity of lactic acid receptors and inhibits host-seeking behavior. It is possible that the transfer of substances from the male accessory glands to the female during copulation might be involved in the production, release, and/or activity of this factor.

We have used microsurgical manipulation of male reproductive tissues in conjunction with behavioral and electrophysiological methods to investigate the effect of mating on host-seeking behavior during oocyte maturation.

#54

PELLET PISTOL METHOD OF TREATING CATTLE WITH INSECTICIDES FOR HORN FLY CONTROL (DIPTERA: MUSCIDAE). T. L. Harvey and J. R. Brethour. Kansas State University, Experiment Station, Hays, Kansas 67601 USA.

Horn fly, *Haematobia irritans* (L.) were controlled for brief periods when cattle were struck with insecticide pellets fired from a CO₂ gas-operated pistol. Pellets contained marking paint which we replaced with 2 milliliters of concentrated insecticide. The pellets shot from a distance of 15-20 meters shattered on impact, splattering the cattle with insecticide. Partial herd treatments of one pellet containing 30% fenvalerate per treated animal always resulted in complete control one day after application, and horn flies were usually controlled for one week. The degree of control was related to the concentration of insecticide and proportion of herd treated. In a single test using an isolated herd of 22 cows, six half-herd applications of 38% permethrin provided 86% control for 15 weeks. Pellets containing various concentrates of commercially available non-pyrethroid insecticides generally controlled horn flies for only one day, probably because the amounts applied by this method were less than that used in conventional methods of application. The possible practical use of the pellet pistol method may have to await the discovery of more effective insecticides.

#55

A NEW TYPOLOGY OF THE MALE GENITALIA IN THE *CULEX PIPPIENS* COMPLEX (DIPTERA: CULICIDAE). T. Ishii, College of General Education, University of Tokushima, Tokushima 770 Japan.

Although the DV/D ratio has been solely used for the measurement of the male genitalia of the *Culex pipiens* complex, it cannot be indicative of the differences in the shapes of the ventral and dorsal arms of the phallosome. To classify further genitalia types in a group of the males that share a similar DV/D value, a new typology of the male genitalia based on a combination of the types of the two arms is herein proposed.

Among the specimens of *Cx. pipiens pipiens*, *Cx. p. quinquefasciatus*, and *Cx. p. pallens* collected from various localities, seven types were discriminated in the ventral arms and 13 in the dorsal ones. The male genitalia types obtained by the three-dimensional classification based upon the DV/D ratio and the two arm-types make possible a new worldwide distribution map of the member sub-species involved.

#56

STUDIES ON THE STRUCTURE AND FUNCTION OF HALLER'S ORGAN OF TICKS (ACARI: IXODIDAE). Jiang Zai-jie*, Chang Chong-yan and Li Guan-min, Department of Biology, Beijing Normal University, Beijing, China 100088.

The Haller's organs of 8 species of genus *Dermacentor* in adult, larva and nymph stages were observed with scanning and transmission electron microscope, and comparisons were made with that of six species of other genera for expound the value of using the morphological features of Haller's organ in taxonomy. The Haller's organ of three species (*D. abakensis*, *D. auratus* and *D. sinicus*) are described for the first time. Distinct differences among stages were found among *D. auratus*, distributed in Oriental region and the palaearctic species of *Dermacentor*. The differences among stages of the same species are analysed. Based on the morphological features of Haller's organ the authors have found some additional characters used in taxonomic study. They are: the shape and situation of porose sensillum and the number of basic discs in the anterior pit, the number and situation of proximal ostium and the form of the pleomorphy within the capsule etc.

The electrophysiological responses of 5 species of ticks to chemical stimuli: ammonia, acetic acid, CO₂, sex pheromone (2,6-dichlorophenol, phenol, p-cresol, salicylic aldehyde) and cold stimulus were investigated. The behaviour reaction to 5 kinds of repellents were observed.

#57

House Dust Mite (Acarina) Fauna in the High Hills of Himachal Pradesh, India. Ram Kumar, Department of Entomology and Apiculture, Dr Y.S. Parmar University of Horticulture and Forestry, Solan, PO Nauni-173230 (India).

The mite fauna of house dust samples was studied. Samples were collected from the general floor sweepings as well as from the dust of bed clothes. The effect of weather conditions on the incidence of various mite species have been observed over the year during summer, rainy and winter seasons. Accordingly three categories of mites are recognised: (i) those having occasional but abrupt fluctuations during the months of severe cold and summer (ii) those having gradual increase with relative constancy before showing fluctuations during rainy season and (iii) those having irregular rapid fluctuations throughout the year. The role of microclimatic conditions in maintaining mite populations in certain samples is emphasized. Of the various species of mites identified *Dermatophagoides pteronyssinus* and *D. farinae* dominated mite counts in all samples in all seasons. The typical habits of people living at high altitudes which change and maintain the micro-environment seem to be responsible for supporting the variations observed in population size and type.

#58

Respiratory and skin disorders as related to House Dust and House Dust mite Sensitivity. Ram Kumar and Neelima R. Kumar, Department of Entomology and Apiculture, Dr Y.S. Parmar University of Horticulture and Forestry, Solan, PO Nauni-173230 (India).

Small children in the age group of 4-9 years suffer frequently from respiratory and skin problems. The habitations and habits of the children bring forth a definite relationship between these disorders and the house dust and house dust mite *Dermatophagoides* spp. laden atmosphere of their homes. Skin prick tests were made with four categories of the children: (i) with respiratory problems; (ii) with skin problem; (iii) with respiratory and skin problems; and (iv) the control with -1, -2, -3 concentration of house dust and house dust mite allergen extract separately. The diameter of the elicited skin wheels reveals that the children suffering from either or both the disorders are in general more sensitive to both the allergen extracts used. The results are suggestive of the fact that these problems in childhood are related to the acarofauna of the habitations and the habits of the children of a particular area.

#59

CULICOIDES VARIIPENNIS (COQUILLET): SEASONAL ABUNDANCE, VOLTINISM, PARITY RATES AND FECUNDITY IN NORTHERN CALIFORNIA (DIPTERA: CERATOPOGONIDAE). A.X. Linhares* & J.R. Anderson, Department of Parasitology, State University of Campinas, SP, Brazil, 13081.

Based on sampling of immatures, trapping of adults and seasonal variation in the nulliparous and parous rates of females, three to four peaks of emergence for *Culicoides variipennis* were detected from August 26 to November 11, 1982, and in 1983, at least six generations occurred from June 9 to November 3. Overwintering mature larvae were found at the breeding sites as early as May 26, 1983. Highest densities of immatures and adults, as well as higher parity rates occurred from late September through October indicating that high risk of disease transmission is likely during that period. In Sonoma County, the 1983 adult survivorship rate was 0.63, corresponding to a daily survivorship rate of 0.89. At all manure lagoons, larvae were found mainly below, or at, waterline, whereas 90% of the pupae were found above the waterline. Lagoons where larvae were not found, also failed to attract large numbers of gravid females, indicating that such lagoons lacked the factors responsible for attracting gravid females to oviposition sites. Females collected early and late in the season were larger than the ones collected during warmer months. There was a significant correlation between female size and the numbers of eggs.

#60

DNA PROBES FOR IDENTIFICATION OF MEMBERS OF THE *ANOPHELES CULICIFACIES* SPECIES COMPLEX. C.A. Malcolm* and Ling Ling Niu, London School of Hygiene and Tropical Medicine, Keppel Street, London WC1E 7HT.

A pBR328 plasmid genomic library was prepared for *Anopheles culicifacies* species B. This was screened differentially with genomic DNA from species A and species B to yield two cloned DNA sequences, one of 3.7 Kb and the other of 2.2 Kb, which both show about 30-fold more hybridisation to total genomic DNA from species B than species A. The two probes termed B13 and B431 have been shown by cross-hybridisation and restriction mapping to be homologous over a region of at least 0.8 Kb. Both probes will distinguish species A from species B, of either sex, at levels down to at least 1/500th of the total DNA routinely obtained from individual mosquitoes, when labelled with ³²P, or 1/200th when labelled with biotin.

#61

EFFECTS OF ENVIRONMENTAL PARAMETERS ON PUPATION SITE SELECTION IN THE STABLE FLY, (DIPTERA: MUSCIDAE). L.J. McPherson* and A.B. Broce, Department of Entomological Sciences, University of California, Berkeley, CA 94720.

Prior to pupation, stable fly larvae *Stomoxys calcitrans* enter a wandering phase which we estimated to be ca. 13 hours, resulting in pupation sites quite removed from the larval habitat. Our results show that initiation and termination of the wandering phase was not rhythmic but occurred randomly. Stable flies are found pupating in a wide variety of habitats. The effect of moisture, light, temperature, pH, osmolality, and conspecific density on site selection and survival was evaluated by means of choice tests. Of the moisture levels tested (50, 68, 89%), number of pupae was highest at 68%. Larvae pupated in the dark when placed in a light gradient, and at a temperature of ca. 27°C., when placed in a temperature gradient. Field measurements of naturally occurring pupation sites demonstrated that wandering larvae selected a broad range of the above habitat parameters in which to pupate. When released into the field, laboratory reared larvae did not appear to relocate under more specific conditions. In summary, the laboratory tested preferences of stable fly larvae were narrower than those observed in the field.

#62

INTRODUCTION AND SPREAD OF AN ASIAN MOSQUITO, *Aedes albopictus* SKUSE (DIPTERA: CULICIDAE), IN THE AMERICAS. C.G. Moore*, D.B. Francy, D.A. Eliason, R.E. Bailey, T.P. Monath, and R.B. Craven, Centers for Disease Control, Fort Collins, Colorado 80522, USA.

In 1985, the Asian "tiger mosquito," *Aedes albopictus*, was discovered in Houston, Texas, USA. In 1986, it was found in three Brazilian states. This mosquito is of public health concern because of its ability to transmit dengue, yellow fever, and La Crosse encephalitis viruses.

Used tire casings infested with *A. albopictus* were intercepted in Seattle, Washington, by the U.S. Centers for Disease Control, and in Oakland, California, by local vector control inspectors. The used tire trade is thought to be the primary means of introduction into the Americas.

By late 1986, *A. albopictus* was found in 47 counties in 12 states; and by 1987, it was found in 63 counties in 17 states. Rapid dispersal of this species appears to be due primarily to movement of used tires in intra- and interstate commerce. The natural rate of spread of *A. albopictus* appears to be between 1 and 2 km/year. Detailed surveys in eight U.S. cities during 1987 showed a decrease in *A. albopictus* abundance with increasing distance from Houston. Our observations are consistent with the hypothesis that Houston was the original site of introduction.

#63

THE SUSCEPTIBILITY OF MANITOBA HORN FLIES *HAEMATOBIA IRRITANS*(L) TO FENVALERATE AND PERMETHRIN. F.S. Mwangala* and T.D. Galloway, Department of Entomology, University of Manitoba, Winnipeg, Manitoba, Canada R3T 2N2.

Horn flies *Haematobia irritans*(L) were collected from cattle at various locations in Manitoba using sweepnets. The flies were then exposed to filter papers impregnated with serial dilutions of either Fenvalerate or Permethrin in petri dishes.

The strains showed resistance factors ranging from 0.1 to 5.5 for Fenvalerate and 0.05 to 14 for Permethrin when compared to the susceptible laboratory strain (Texas; Kerrville). Of the 16 herds sampled, only the flies from Glenlea, West of Morden and North of Carman showed 4.12, 5.50 and 4.50-fold resistance to Fenvalerate and 2.11, 1.94 and 14.0-fold resistance to Permethrin respectively. However, the numbers of flies on these herds were small compared to untaged herds indicating that ear tags were still affording some control. The strains that were more susceptible than the laboratory strain were collected from untreated herds. Higher tolerances were observed in strains from herds where ear tags have been used for at least four years. No horn flies were observed on eight farms, most of which have used ear tags for not more than three years.

#64

THE HIGHLY EFFECTIVE INSECTICIDAL FLY BAIT, MUSCA RED, FOR HOUSE FLY, *MUSCA DOMESTICA* (DIPTERA). T. Negishi, A. Kamada, Y. Utsumi, M. Kamel, Department of Biochemical Project, Earth Chemical Co., Ltd., 923 Kagasuno, Kawauchi, Tokushima, 771-01 Japan.

A sugar granule formulation of resmethrin containing cis-9-tricosene was more effective than the same granule formulation containing other insecticides such as methomyl, propoxure and prothiophos in the laboratory tests. Efficacy tests were conducted by spraying 1-2g baits per m² in three egg ranches having a cage layer poultry system. Flies that landed in the treated area found the baits easily, fed, and were knocked-down or flushed out from the test sites within several minutes: they died within a few hours. One hour after treatment, the number of flies in the square grids were reduced to less than 10% compared to that before treatment. Efficacy of the fly bait persisted for about a week.

#65

EXPRESSION OF AUTOGENY IN MOSQUITO POPULATIONS ON THE SOUTH YAMAL. N.V. Nikolajeva, Institute of Plant & Animal Ecology, USSR Academy of Sciences, Sverdlovsk 620 008, U.S.S.R.

After three-year studies the degree of autogeny in populations of *Aedes communis* Deg., *A. pullatus* Coq. and *A. hexodontus* Dyar (Diptera: Culicidae) was defined. In various seasons the proportion of autogenous females in *A. communis* was stable enough amounting to 30-37%. At the same time considerable variations in the degree of autogeny (from 12 to 80%) in some micropopulations of this species were observed. Variations in the ratio between autogenous and nonautogenous individuals reflected a dissimilar effect of various combinations of ecological factors upon the larvae of mosquitoes. In 1973 the females of *A. communis* were highly autogenous, their larval development taking place under conditions of high temperatures and density. In 1974 and 1979 the proportion of autogenous females of this species was higher if their larvae developed at lower density. The data obtained show the presence of balanced polymorphism on autogeny in mosquito populations studied.

#66

REACTIONS TO MOSQUITO BITES AND ELISA WITH *Aedes albopictus* IN JAPANESE (DIPTERA: CULICIDAE). K. Oka* and N. Ohtaki, Department of Dermatology, Tokyo Medical and Dental University, Bunkyo-ku, Tokyo, Japan

The human skin reaction to mosquito bite consists of immediate and delayed reactions. It was suggested that repeated exposures change the reaction from stage I to stage V: I. No reaction; II. delayed reaction only; III. immediate and delayed reactions; IV. immediate reaction only; V. non-reaction. About 160 Japanese volunteers, aged 1 to 68 years old, were exposed to *Aedes albopictus* which is one of the most common species in Japan. The correlation between the age and the stage of bite reaction was high, which support that theory.

To further study the mechanism of the reaction, the following experiments were done; 1) Detection of histamine in the crude salivary glands extract (SG) by HPLC revealed that a pair of salivary glands contained less than 1 ng of histamine. 2) SG was divided into a lower molecular weight fraction (mol. WT. < 10,000) (LMWF) and a higher molecular weight fraction (HMWF). Intradermal skin tests were done with both fractions, but only HMWF elicited a positive reaction which was consistent with bite reaction. 3) ELISA to examine Ig E antibodies to SG antigen was done in about 120 subjects. There is a good correlation between immediate bite reaction and titers of antibodies to SG antigen. These results confirmed that the molecular weight of SG causing the bite reaction was higher than 10,000 and that immediate reaction was allergic in nature (Coombs I type). The correlation between skin reactions and titers of Ig G and Ig G₄ antibodies to SG antigen is now being studied.

#67

TOXICITY OF CITRUS PEEL OIL TO *CULEX ALBIVENTRIS*. J.I. Olaifa¹, J.S. Afolabi² and A.O. Jibodu, ¹Department of Plant Sciences, Obafemi Awolowo University, Ile-Ife, Nigeria; and ²Department of Environmental Health and Epidemiology, Ile-Ife, Nigeria.

In a laboratory test in which *Citrus* peel oils (*Citrus sinensis* (L.) Osbeck, *Citrus aurantium* (L.), *Citrus reticulata* Blanco and *Citrus paradisi* Macf.) were introduced onto paper discs in covered glass beakers, the oil vapour effected a quick knockdown of adult female mosquitos *Culex albiventris*. Knocked down insects never recovered. The higher the concentration of *Citrus* peel oil, the faster the knock-down time for the four *Citrus* species. *C. paradisi* gave the fastest knockdown (KT₅₀, 30 min) at 2 µl/disc while *C. sinensis* performed better (KT₅₀, 5 min) when the concentration of the oil was 4 µl/disc. The implication of mosquito control in Nigerian homes with locally produced natural insecticide is discussed.

#68

EFFECTS OF THIOTEPA ON CHROMOSOMES OF *CULEX P. FATIGANS* (DIPTERA : CULICIDAE). H.P. Puttaraju, Department of Sericulture, Bangalore University, Bangalore-560 009, India.

In recent times, the work on genetic control of insect pests has been very much facilitated by the use of chemosterilants. The present investigation has been carried out with an aim to study the cytological effects of thiotepa, an important chemosterilant in the brain cells of mosquito *Culex p. fatigans*. Two day old larvae of the taxon were reared in 25ppm and 5ppm of thiotepa separately. The chromosomes prepared from the brain cells of mid fourth instar larvae reveal that 25ppm of thiotepa induces chromosomal aberrations at a higher rate. The frequency of various kinds of chromosomal abnormalities were analysed. The nature of action and damage caused by thiotepa are discussed.

#69

IMMUNOCYTOCHEMICAL AND ULTRASTRUCTURAL STUDIES OF RIFT VALLEY FEVER VIRUS IN SELECTED AFRICAN MOSQUITO SPECIES W.S. Romoser*, & K. Lerdthusnee, Dept. of Zoological & Bio-Medical Sciences, Ohio University, Athens, OH 45701, U.S.A. M.E. Faran, K.J. Linthicum, L.A. Patrican & C.L. Bailey, U.S. Army Medical Research Institute of Infectious Diseases, Ft. Detrick, Frederick, MD 21701, U.S.A.

We have applied immunocytochemistry and electron microscopy in studies of dissemination of Rift Valley fever (RVF) virus among the tissues of infected *Culex pipiens* (the 1977 RVF epizootic/epidemic vector in Egypt) and *Aedes mcintoshi* (a possible interepizootic maintenance host in Kenya). Important findings include evidence that: (1) virus from an infectious blood meal can enter the hemocoel via cells at the foregut-midgut junction; (2) dissemination of virus from the midgut into the hemocoel occurs sporadically over many days following an infectious blood meal; (3) once virus escapes from the midgut, infection of the various tissues in the hemocoel occurs rapidly; (4) the most common sequence of tissue infection following escape from the midgut lumen is first the posterior region of the foregut which forms an intussusception with the cardiac epithelium of the midgut followed by the fat body and then the remaining susceptible tissues; and (5) developing *Ae. mcintoshi* eggs can be infected from the hemocoel.

#70

BEHAVIOURAL AND ELECTROPHYSIOLOGICAL RESPONSES OF TSETSE FLIES (DIPTERA: GLOSSINIDAE) TO VARIOUS PHENOLS. R.K.Saini, International Centre of Insect Physiology and Ecology (ICIPE), P.O. Box 30772, Nairobi, Kenya.

The active fraction of buffalo urine, a potent attractant for *Glossina* sp. has been shown to be composed of seven phenolic compounds which include phenol, 3- and 4- cresols, 3- and 4- ethylphenols and 3- and 4-n-propylphenols. Behavioural (antennal movements) and electrophysiological (EAG) studies were undertaken to determine the relative importance of these phenols in conferring high activity to the blend. The most stimulating of the seven phenols to both *G.pallidipes* and *G.m.morsitans* was 4- cresol. Both species were least stimulated with phenol itself. EAG responses indicate that 4- cresol for *G.m.morsitans* and 3- propylphenol for *G.pallidipes* were the most stimulatory. Both studies indicate that responses differ between species to various phenols and that 4- cresol and 3- propylphenol play an important role in conferring high activity to the blend.

#71

INFESTATION OF *CULICOIDES NUBECULOSUS* (CERATOPOGONIDAE) WITH MICROFILARIAE OF DIFFERENT HOSTS IN THE LABORATORY. H. Schulz-Key* and J. Fahrner, Institute for Tropical Medicine of the University, D-7400 Tübingen, Federal Republic of Germany.

Large numbers of infective larvae of *Onchocerca* species, particularly of *O. volvulus*, are urgently needed for immunological and biochemical investigations. However, for most of them simuliids are the natural vectors, which are difficult to rear and to feed in the laboratory. That is why a potent surrogate vector is looked for. So we started with mass rearing of *Culicoides nubeculosus*, the natural vector of *Onchocerca cervicalis* and *O. gutturosa*, feeding them through artificial membranes. - Microfilariae of the following species were isolated from the hides of cattle, red deer (*Cervus elaphus*) or roe deer (*Capreolus capreolus*) and were suspended in cattle blood: *O. gutturosa*, *O. gibsoni*, *O. tarsicola*, *O. flexuosa* and *Dipetalonema rugosicauda*. All microfilariae could be ingested through the membrane except for those of *O. tarsicola*, which were too large. Microfilariae of the other species were also able to penetrate the peritrophic membrane and invade into the thorax of the midge. Microfilariae of *O. gutturosa* developed to the infective stage within 9 days at a temperature of 25°C. *O. flexuosa* developed to the "sausage stage", while the other filarial species failed. - Our laboratory is supported by the Commission of the European Communities (CEC).

#72

ZYMOGRAM COMPARISON AMONG MOSQUITO LARVAE OF GENUS *TOXORHYNCHITES* IN ASIA (DIPTERA: CULICIDAE). M. Tsukamoto* and M. Horio, Department of Medical Zoology, University of Occupational and Environmental Health, Yahatanishiku, Kitakyushu 807, Japan

Biochemical characterization of mosquitoes was attempted by comparing electrophoretic zymograms in polyacrylamide gel plates. *Toxorhynchites* species examined at the 4th instar were: *indicus*; *bickleyi*, *quasiferox*, *towadensis*; *metallicus*, *klossi*, *gravellyi*, *kempyi*, *leicesteri*, *yaeyamae*, *yamadai*, *mag-nificus*; *minimus*; *amboinensis*, *splendens*; sp. (Okinawa), sp. (Palawan), sp. (Kinabalu), etc. Enzymes compared were: alcohol-, lactate-, glucose-6-phosphate-, xanthine-dehydrogenases (ADH, LDH, G6PD, XDH), malic enzyme (ME), hexokinase (HK), esterases (Est), leucine aminopeptidase (LAP), glucosylphosphate isomerase (GPI), phosphoglucosylmutase (PGM), etc. A single major band was detected in ADH, LDH, ME, XDH and GPI, but several bands were observed in HK, Est, LAP and PGM. Homogenates of digestive tract showed different banding patterns from those of degutted larval body in LDH, G6PD, HK, Est, LAP, etc. Differences in electrophoretic mobility between species were recognized in LDH, G6PD, HK, Est, LAP, etc. In cases of ME and PGM, respectively, most species examined had only a single mobility. Thus, isozyme patterns did not correlate with a taxonomic grouping system within the genus *Toxorhynchites*.

#73

SUSCEPTIBILITY OF *SIMULIUM ORNATUM* (DIPTERA: SIMULIIDAE) AND *CULICOIDES NUBECULOSUS* (DIPTERA: CERATOPOGONIDAE) TO TWO *ONCHOCERCA* SPP. (NEMATODA: FILARIOIDEA) FROM CATTLE.

G. WAHL and J. DOHNAL* Institute for Tropical Medicine of the University, D-7400 Tübingen, FRG.

Bovine onchocerciasis in Europe is caused by two species of filarial parasites: *Onchocerca lienalis* and *Onchocerca gutturosa*. While the first is known to be naturally transmitted by *S. ornatum*, *O. gutturosa* can develop in *C. nubeculosus* under laboratory conditions. It has been suggested that any species of *Onchocerca* is transmitted either by simuliids or by ceratopogonids, but never by both. As *O. lienalis* and *O. gutturosa* are closely related, we were interested, if this "complementary vector-specificity" would apply here also. A sample of *O. lienalis* microfilariae introduced into *S. ornatum* by intrathoracal injection and into *C. nubeculosus* by membrane feeding showed development to infective larvae only in the black fly. On the other hand infective larvae of *O. gutturosa* were recovered from *C. nubeculosus*, but not from *S. ornatum*.

The microfilariae of the two species are morphologically very similar and cannot be identified by their location in the skin. By "cross-infection", however, we were able to characterize the parasites.

#74

ATTACHMENT AND FEEDING OF THE BROWN EAR-TICK *RHIPICEPHALUS APPENDICULATUS* ON ARTIFICIAL MEMBRANE S.M. WALADDE*, S.A. OCHIENG and E.D. KOKWARO, International Centre of Insect Physiology and Ecology (ICIPE), P.O. Box 30772, Nairobi, Kenya.

The bandruche membrane was prepared by coating one surface with a thin layer of rubber cement mixed with pieces of rabbit hair. This prevented the membrane from leaking and formed a rough surface which provided tactile stimulation facilitating tick attachment. With the coated surface facing upwards, the membrane was fixed over a 520mm diameter and 10mm deep reservoir, thus forming a feeding chamber. The chamber bearing inlet and outlet orifices fitted with 2mm internal diameter teflon tubings was later sterilized under UV lamp. Cattle blood serum was sterilized using a 0.4µm millipore filter and then injected into the chamber. The membrane surface was smeared with a concentrate of n-hexane cattle ear-wash to provide the necessary olfactory stimuli which appears to arrest tick movement. The entire set-up was maintained at 35-37°C. Adults of *R. Appendiculatus* confined on the membrane attached properly, fed and partially gorged on the fluid below the membrane.

#75

REPELLENT AND TOXIC EFFECTS OF PERMETHRIN AND N,N-DIETHYL-META-TOLUAMIDE ON THE TSETSE *GLOSSINA MORSITANS* WESTWOOD (DIPTERA: GLOSSINIDAE). R.A. Wirtz*, J.A. Hallam, L.W. Roberts, L.C. Rutledge and R.G. Andre, Entomology, Walter Reed Army Institute of Research, Washington, DC 20307-5100, USA.

Permethrin (PER) and N,N-diethyl-meta-toluamide (DEET) were evaluated for their repellent and toxic effects on the tsetse *Glossina morsitans* using a dose-response testing procedure on white rabbits. The 0-hour ED₉₅'s were 0.068 and 0.09 mg/cm² for DEET and PER, respectively. Flies often exhibited loss of coordination and excessive wing beating 2-3 min after exposure to PER. Consequently, when testing with DEET, 29% of the flies were feeding at the end of the test period as opposed to 1% in the PER tests. The 24-hr mortalities were 8-13% for DEET and 97-100% for PER. Biting counts on DEET-treated skin and PER-treated fabric were recorded also using a dual choice method: (1) use of untreated fabric reduced biting from 143% (untreated skin) to 0%; (2) no differences between ethanol- or PER-treated fabrics were observed (1% bit); (3) 82% of flies bit on ethanol-treated skin versus 0% on PER-treated fabric; and (4) 9% bit on DEET-treated skin versus 0.5% on PER-treated fabric. The use of fabric alone greatly reduced biting activity under the conditions described; however, the flies then selectively fed on exposed skin. The use of DEET on exposed skin in conjunction with PER-treated clothing appears to be an excellent means of reducing disease transmission by tsetse flies but requires field validation.

#76

CUTICULAR HYDROCARBONS OF HORSE FLIES (TABANIDAE DIPTERA) FROM OKLAHOMA R.E. Wright*, K.L. Hoppe and J.W. Dillwith, Department of Entomology, Oklahoma State University, Stillwater, Oklahoma 74078.

Analysis of hexane extracts of several species of horse flies by thin layer chromatography showed the cuticular lipids to be composed of a mixture of sterols, free fatty acids, triglycerides, wax esters and hydrocarbons. Hydrocarbons were present in each species examined, however, this was not the predominant fraction in any species. The hydrocarbons were isolated by chromatography on silica gel, and consisted of a mixture of n-alkanes and methyl branched alkanes. No alkenes were present in any species examined.

An analysis of the cuticular hydrocarbons of 23 females and 5 male *T. abactor* indicated there was no difference in the hydrocarbon profile between males and females. There also was no difference in the cuticular hydrocarbon profiles of specimens that had been pinned for 34 years, 10 years, 1 year, or specimens that had been frozen for 1-4 years or fresh specimens.

The cuticular hydrocarbon profile of 11 species of *Tabanus* was very distinct for each species and easily differentiated between three species, *T. abdominalis*, *T. limbinevis* and *T. sulcifrons*, that are difficult to differentiate by morphological characteristics.

#77

DISTRIBUTION OF *CULICOIDES* SPECIES IN WYOMING WITH EMPHASIS ON *CULICOIDES VARIIPENNIS*. P.E. Yeager*, F.R. Holbrook and W.L. Kramer¹, USDA, Agricultural Research Service, Arthropod-borne Animal Diseases Research Laboratory, P.O. Box 3965, Laramie, Wyoming, USA 82071 and ¹Nebraska State Health Department, P.O. Box 95007, Lincoln, Nebraska, USA 68509.

A light-trap survey of *Culicoides* species with emphasis on *Culicoides variipennis* the principal biological vector of bluetongue virus in North America was conducted in Wyoming during June-August 1986. Elevations ranged from 1067-2288 m, with the diversity of species lessening with an increase in altitude. *C. variipennis* distribution ranged from 514 flies at 1067 m to two flies at 1923 m. A total of 14 species of *Culicoides* species were trapped throughout the state.

#78

A PRELIMINARY INVESTIGATION OF THE SANDFLIES AND THEIR RELATION TO KALA-AZAR IN SOUTHERN GANSU AND NORTHERN SICHUAN. Xiong Guang-hua, Jin Chang-fa and Hong Yu-mei, Department of Vector Biology and Control, Institute of Parasitic Diseases, CAPM, 207 Rui Jin 2 Rd., Shanghai 200025, P.R. China.

In southern Gansu and northern Sichuan *Phlebotomus chinensis* is the most common sandfly; large in number with a wide distribution. It was discovered that two different types of *P. chinensis* exist in localities 980 to 2370 metres above sea level. A large type exists above 2000 metres whereas a smaller type exists below 1500 metres. The two types occur together in locations between 1500 and 2000 metres above sea level. Ecological and epidemiological data indicate that the large type of *P. chinensis* is a favourable vector in the mountainous region above 1800 metres, where it transmits visceral leishmaniasis to canines with a zoonotic focus. Canine visceral leishmaniasis was commonly found in regions below 1600 metres where the small type of *P. chinensis* is believed to be the disease vector.

#79

ULTRASTRUCTURAL STUDIES ON MORPHOLOGY OF EXOCHORION OF ANOPHELES (CELLIA) MINIMUS FORMS A & B BY SCANNING ELECTRON MICROSCOPY (DIPTERA:CULICIDAE). Y. Yu*, J.J. Liang and X.M. Peng, Department of Vector Biology and Control, Institute of Parasitic Diseases, CAPM, Shanghai 200025, P.R. China

Comparative studies were made under the scanning electron microscopy on the exochorion of Anopheles (Cellia) minimus s. l., F₆ and F₈ of Guangxi strain being observed. Microstructural of the exochorion, such as the micropylar area, number of oviscapt dishes, lobe tubercles, deck, float and granules on the egg surfaces of An. (Cel.) minimus were described. Distinct differences were found in the ultrastructure of An. (Cel.) minimus forms A & B and interspecific variations, which was related with the dish numbers.

#82

COMPARISON OF THE TOXICITY OF FIVE ISOLATES OF ACTINOMYCETES AGAINST MOSQUITO LARVAE. M. Al-Doori* & M. Al-Saadi (Iraq)

No Abstract

#80

BLOOD MEAL ANALYSIS OF CULEX VISHNUI, MOSQUITO VECTOR OF JAPANESE ENCEPHALITIS (JE) ENDEMIC IN PARTS OF WEST BENGAL, INDIA. D.K.Choudhuri, Department of Zoology, Burdwan University, Burdwan, West Bengal, India.

For ascertaining host-preference of C.vishnui, mosquito vector of JE, blood meal analysis was done in 533 C.vishnui mosquitoes, 248 and 305 captured from human habitations and cowsheds respectively. Human, bovine, porcine and avian antisera were used to know sources of blood meal. Bovids were the most preferred hosts of C.vishnui, 64.8% being positive for bovine blood. In order of merit, the 2nd, 3rd and 4th preferred hosts were man (20.8%), pig (9.9%) and bird (4.6%).

Preference for blood meal varied according to biotope. When mosquitoes were collected from human habitations, human, bovine, porcine and avian blood indices were 26.1, 61.9, 8.4 and 3.5 respectively; but when they were collected from cowsheds corresponding indices were 16.2, 67.1, 11.2 and 5.4 respectively. So, the risk of being bitten by C.vishnui and contacting JE disease seemed more in human habitations. In mosquito-animal-mosquito cycle of maintaining JE virus in nature C. vishnui played some part, as about 10% and 4.6% mosquitoes were positive for porcine and wild birds respectively.

In 50 C.vishnui human habitations (22), and cowsheds (28) double blood meal was detected. Combinations were human+bovine (13), human+porcine (4), human+avian (3) and bovine+porcine (2) in human habitations; and human + bovine (16), human+porcine (5) and bovine+porcine (7) in cowsheds. It was possible for C.vishnui to transmit JE virus even mechanically from the infective hosts to healthy ones.

#81

CONTROL OF IMMATURE MOSQUITOES WITH A SINGLE-, JOINT-, OR MULTI-ACTION POLYMER-BASE INSECTICIDE DELIVERY SYSTEM. R. Levy*, M.A. Nichols and T.W. Miller, Jr. Lee County Mosquito Control District, Post Office Box 06005, Fort Myers, Florida 33906, U.S.A.

Investigations were conducted on the control of immature mosquitoes with a series of novel polymer-base controlled release formulations of a monomolecular surface film (Arosurf® MSF) and a larvicidal bacilli (Bacillus thuringiensis var. israelensis or Bacillus sphaericus) or a conventional organophosphate pesticide (Abate® 4-E). Results of laboratory and field evaluations against larvae and pupae of Culex and Aedes species with agglomerated and non-agglomerated polymer-base insecticidal compositions at application rates of ca. 3 - 5 lbs/acre indicated that two or more insecticidal agents can be simultaneously released at varying rates from a polymer matrix in pretreatment (dry) or direct treatment (aquatic) mosquito habitats, and produce larvicidal and pupicidal action that is superior to the control potential of the formulation components. Results also indicated that the polymer matrix alone can be used as a mosquito control agent in certain habitats. The ability of the polymer matrix to protect one or more active insecticidal agents from degradation or loss due to UV, oxidation, run-off, microbial attack, etc., in pretreatment mosquito habitats is further discussed.

BIOLOGICAL CONTROL IN THEORY AND PRACTICE. W.W. Murdoch, Department of Biological Sciences, University of California, Santa Barbara, CA 93106, USA.

In successful biological control the pest is kept below a critical density in the area of concern. It would be valuable to know which features determine whether or not a biological control system is successful, and whether these features reflect principles that apply broadly. Existing theory seeking to elucidate such principles focuses on the stability of local pest-enemy interactions, and views the enemy as a source of stability. Local interactions do appear to be stable in some systems, but successful control may not require such stability, and in some situations stabilizing mechanisms may reduce the degree of control.

This talk will discuss the connection between theory and what is known about some cases of successful biological control. It will examine the probable effects of the enemy on the stability of the interaction, mechanisms that enhance the probability of the system's persistence, and features of the interaction that may be associated with reliably low pest density.

INSECT DECISION RULES AND BIOLOGICAL CONTROL. Bernard D. Roitberg, Centre for Pest Management, Behavioural Ecology Research Group, Department of Biological Sciences, Simon Fraser University, Burnaby, BC CANADA V5A 1S6.

Optimality approaches, when used to study the foraging of parasites for hosts, has often been criticized because of the complexity of the required analysis and for a lack of realism. I will counter these criticisms, first by pointing to the errors in their logic and second by showing how the use of simple rules by insect parasites can provide optimal solutions to complex problems. Using realistic, behaviour-rich examples, I will concentrate on two problems: (1) patch time allocation and (2) oviposition decisions. Finally, I will expand my discussion to consider the effects of insect decision rules on biological control.

HOST DISCRIMINATION AND LARVAL COMPETITION IN SOLITARY INSECT PARASITES. M. Mackauer, Centre for Pest Management, Simon Fraser University, Burnaby, British Columbia, Canada V5A 1S6

The decision by a parasite female to accept or to reject for oviposition a previously parasitized host (= host discrimination) depends on the probability of offspring survival. In solitary parasites, hosts parasitized by a conspecific female are normally rejected, whereas those containing non-conspecific eggs and larval stages may be accepted. The modalities of inter- and intraspecific host discrimination and larval competition are discussed with reference to aphid parasites (Hymenoptera: Aphidiidae; Aphelinidae). Although females generally behave opportunistically, host discrimination is not a precise mechanism, especially if host quality varies among different members of a parasite guild. Theoretical considerations are insufficient to predict the outcome of multiple introductions for biological control, in particular of closely related species having similar niche requirements.

ENVIRONMENTAL FACTORS AFFECTING THE COMPOSITION OF PARASITOID GUILDS. J. C. Miller. Department of Entomology, Oregon State University, Corvallis, Oregon 97331, U. S. A.

Why are certain species abundant or rare and what environmental factors cause changes in their relative abundance? Environmental factors such as habitat temporal stability, host density, host specificity and alternate hosts, host plant, insecticides, climate, interspecific competition, reproductive potential, predators, and hyper parasitoids may greatly influence parasitoid guild composition. If information on the interactions among these factors may explain past failures and successes in biological control then future interests may be addressed as well. Studies on the parasitoids of Lepidoptera on peppermint and alfalfa in Western Oregon are presented to illustrate some of the dynamics of parasitoid guilds.

PLANT DIVERSITY AND NATURAL ENEMY EFFICIENCY IN AGRO-ECOSYSTEMS. H.F. van Emden, Departments of Horticulture and Pure & Applied Zoology, University of Reading, Reading, Berks., United Kingdom, RG6 2AT.

Plant diversity can affect natural enemies of crop pests by providing overwintering sites, adult food, alternative and alternate prey, by changing the crop background and through diversionary and mosaic effects. Experimental evidence for enhanced natural enemy efficiency is frequently associated with interventions in conflict with modern agricultural systems, but there have been some novel re-conciliations. Although it is easy to be convinced that biological control of any magnitude requires some plant diversity to be retained in intensive agriculture, the scale of such diversity is very much open to question.

INTRODUCTION STRATEGIES IN CLASSICAL BIOLOGICAL CONTROL. L. E. Ehler, Department of Entomology, University of California, Davis, California 95616, USA.

Introduction strategies in classical biological control of insect pests have been a matter of considerable debate in recent years. Two extreme positions are as follows: (1) conduct minimal preintroductory investigations and simply release all suitable natural enemies with the hope that the "best" species or combination of species will be sorted out in the field (empirical approach); or (2) conduct thorough preintroductory investigations so as to determine the "best" species or combination of species for a given situation (predictive approach). Each approach is evaluated and criticized. It is suggested that the type of introduction strategy employed should be a function of the nature of the problem to be solved. In this way, there will be a place for both the empirical and predictive approaches in modern biological control.

GENETIC VARIABILITY IN PHYTOPHAGOUS, PREDACEOUS AND PARASITIC ARTHROPODS. R. T. Roush, Department of Entomology, Comstock Hall, Cornell University, Ithaca, New York, 14853, U. S. A.

Particularly in view of their economic importance in biological control, the extent of genetic variability in predaceous and parasitic arthropods is surprisingly poorly known. Although there are somewhat better data available on phytophagous species, much of the variability that has been measured has still not been shown to be relevant to genetic fitness or performance in biological control. Case studies of the genetic variability in phytophagous, predaceous and parasitic arthropods will be critically reviewed with emphasis on some possible areas and approaches for future research and applications in biological control.

BIOLOGICAL CONTROL: ART OR SCIENCE? REVISITED.

Jeff Waage, CAB International Institute of Biological Control (CIBC), Silwood Park, Ascot, Berks. UK SL5 7PY

Does fundamental ecological research really have much to offer the practice of classical biological control? If so, why does theory rarely play an obvious role in the decisions made in biocontrol programmes? This paper surveys the scientific needs of current programmes against exotic insect pests and compares to this the often different emphasis of basic research. It then focuses on recent ecological, behavioural and evolutionary approaches which may help solve practical problems, and considers the predictive power they may ultimately confer on the practitioner.

QUANTITATIVE EVALUATION OF NATURAL ENEMIES. A.P.

Gutierrez, Division of Biological Control, University of California, Berkeley, California, USA 94706.

Evaluating the impact of natural enemies on pest populations requires sound ecological theory, rigorous sampling procedures to gather the needed biological data, and the development of models that enable comparison of the observed and predicted population dynamics of the various components of the system studied. Basic unresolved questions exist in each of these areas. This paper addresses these issues emphasizing how the appropriate biological data may be gathered efficiently and how realistic multitrophic level models may be easily formulated and used to assess the economic benefits of biological control. The commonalities between trophic levels are emphasized.

ENVIRONMENTAL IMPACT OF INTRODUCED BIOLOGICAL-CONTROL AGENTS. P. Harris, Research Station, Agriculture Canada, Regina, Saskatchewan, Canada, S4P 3A2.

All effective biocontrol agents have ecological impact and these are often viewed differently. Thus biocontrol must be done as a matter of public interest. Three types of impacts are recognized. a) On the host species. Normally biocontrol agents are only acceptable if they have a narrow host range. This is particularly true if the target is a plant or vertebrate but there is increasing concern about insects. b) On replacement species. Normally biocontrol of a dominant pest results in a mixed community of several species at a low density. This is particularly noticeable with plants. However, if there is a parasite free competitor for the niche, it may replace the pest. If there is only one organism in a niche, biocontrol may leave the niche largely empty. c) On other organisms. The impacts are normally minor but organisms often change their diet with changes in food availability.

Impact also varies with agent behaviour. Warm blooded vertebrates may inflict more pressure on populations of less common prey than on the most common, in order to obtain dietary variety. The White Amur fish tends to consume food in its proportion of abundance regardless of their preferences. In contrast, insects tend to consume the commonest food.

ECONOMIC IMPACT OF BIOLOGICAL CONTROL OF WEEDS AND INSECTS C.A. Tisdell, Department of Economics, University of Newcastle, N.S.W., Australia 2308.

There has been little systematic assessment of the economic impact of biological control of weeds and insects in agriculture but evidence indicates large benefit/cost ratios. However, the nature of biological control covers a wide spectrum, and it is at least necessary to distinguish between classical, augmentative and inundative control. In economic terms, classical control is akin to a public good whereas inundative is a private good. A variety of methods are used to measure or at least infer the economic impact of biological controls. These include changes in the level of pest populations, variation in yields or levels of production, cost savings (e.g. due to reduced pesticide use), increases in farm revenue or receipts, rises in net farm incomes or profits, variations in land values and private and social cost benefit analysis. These methods and some 'principles' are illustrated and critically reviewed, paying particular attention to Australian studies such as those on the control of *Echium* species and on *Chondrilla juncea*. While some errors in economic assessment are virtually unavoidable, especially for prospective rather than retrospective evaluation, and imperfect decisions can be economically optimal, inappropriate methodology for economic evaluation seems less excusable.

HOST PLANT UTILISATION IN THE PLANTHOPPERS (HOMOPTERA: AUCHENORRHYNCHA: DELPHACIDAE). M. R. Wilson, CAB International Institute of Entomology, 56, Queen's Gate, London, SW7 5JR, UK.

The planthopper family Delphacidae is the largest of the Fulgoroidea families with almost 2000 species worldwide. Some are serious pests of crops such as rice, sugarcane, maize and sorghum. Most species are associated with Gramineae, Juncaceae and Cyperaceae but certain groups are found on ferns and others on a range of dicotyledons. Known host associations have been surveyed and reviewed for the entire family. These associations have been compared with current ideas on the phylogeny of the group.

VARIABLE LIFE HISTORY PATTERNS AND REPRODUCTIVE STRATEGIES IN PLANTHOPPERS. R.F. Denno, Department of Entomology, University of Maryland, College Park, Maryland 20742, USA.

Wing dimorphism in planthoppers provides an ideal opportunity for examining trade-offs between flight capability and reproduction. Comparisons between migratory (macropterous) and sedentary (brachypterous) wing forms of nine species show that macropters with large thoraces and fully developed wings maintain a greater investment in flight apparatus than brachypters with small thoraces and reduced wings. Associated with greater flight capability in the macropter compared to the brachypter are shorter adult life in some species, decreased total fecundity in many species, and delayed age of first reproduction in all species. There is no general tendency among planthopper species for macropters to develop slower as nymphs compared to their flightless counterparts. The reproductive delay and reduced fecundity of the volent wing form of planthoppers supports the notion that flight capability is costly and that trade-offs between flight and reproduction exist.

NUTRITIONAL ECOLOGY AND FEEDING PHYSIOLOGY OF PLANTHOPPERS. A.G. Cook & S. Woodhead *, Overseas Development Natural Resources Institute, College House, Wrights Lane, London, UK. W8 5SJ.

Feeding strategies amongst planthoppers and the patterns of behaviour which lead to effective exploitation of the host plant are discussed. The manner in which feeding behaviour of some pest species of planthoppers is affected by resistance in operation are reviewed in relation to what is known of normal feeding behaviour on susceptible hosts. The implications of varietal resistance for planthopper population development and dispersal are described and the value of this information for devising management strategies which maximise the benefits from available resistant varieties are considered.

THE REGIONAL DYNAMICS OF PLANTHOPPER POPULATIONS. I.J. Perfect* and J.I. Magor, Overseas Development Natural Resources Institute, 127 Clerkenwell Road, London EC1R 5DB.

Many species of planthopper (Homoptera:Delphacidae) are adapted to exploit transient habitats through adult dimorphism, having brachypterous forms with high reproductive potential and macropterous forms adapted for dispersal. The Brown Planthopper, *Nilaparvata lugens* Stal, together with a number of other species found on tropical and temperate rice, displays this characteristic particularly well. This insect has become a major pest of rice throughout Asia in the last two decades and been the subject of very considerable research effort. This has led to a good understanding of the behavioural, physiological, genetic and ecological mechanisms by which it maintains its dominance over a wide distribution range in both temperate and tropical agroecosystems. The paper reviews these mechanisms, with particular reference to patterns of population development and dispersal, and seeks to draw parallels with other planthopper species adapted to different host plants and with different geographic ranges.

LONG DISTANCE MIGRATION IN PLANTHOPPERS. R. Kisimoto, Entomology Laboratory, Faculty of Bioresources, Mie University, Tsu, Mie, Japan 514.

Evidences of long distance migration of the planthoppers infesting rice plants and other gramineous plants have been accumulated on land and sea in East Asia. Northwards (pole directed) movements are mostly manifested in the strong winds appearing near the frontal system. The low level wind maxima which appear at 500-1000m high above the sea level are plausibly considered to carry small insects over the East China Sea. Wind direction shows slight but consistent difference between insect-carrying and non-carrying winds at this elevation.

Most of the migrating planthoppers, predacious mirid bugs and small moths are not able to overwinter in the destined area, but certain planthoppers, such as, *Laodelphax striatellus* and *Metadelphax propinqua*, distribute commonly in the temperate region. Spiderlings of mostly Tetragnathidae are also included in the catches. These facts suggest that migration of small insects is controlled by wind and there is no choice of destination for the insects. Dragonflies seem to move as self-controlled.

Recent evidences show that geographical differentiation occurs in the wing-form determination. The short-wing form is favoured by staggered cultivation of rice plants in the tropics.

PREDATOR-PLANTHOPPER INTERACTIONS. H.G.DÖBEL* and R.F.DENNO, Department of Entomology, University of Maryland, College Park, Maryland, 20742, USA.

Results from several studies show that spiders are important predators of planthoppers in agricultural as well as natural ecosystems. In rice systems, spider populations increase and planthopper populations decrease when levels of food availability are increased artificially by supplementation. Conversely, removal of spiders by insecticides treatments or cage excluders results in significant increases in planthopper densities, confirming the impact of spider predation. Variation in the relationship between spider and planthopper densities is explained in the context of initial seasonal population size, predator lags and aggregative numerical responses. Concerning biological control, findings show that general predators such as spiders should be considered as effective agents under certain circumstances. However, we challenge that spiders are able to regulate planthopper populations in the traditional theoretical sense.

PARASITE-PLANTHOPPER POPULATION DYNAMICS. Donald R. Strong, Department of Biological Science, Florida State University, Tallahassee, Florida 32306-2043, U.S.A.

Anagrus species (Hymenoptera, Mymaridae) have yielded the best data on host-parasite codynamics for planthoppers. These egg parasitoids show the full range of correlations between host density and parasitism rate: positive, negative, and no correlation. Few data on adult wasp densities have been taken, so functional responses are not well known.

For *A. delicatus* and its host *Prokelisia marginata*, parasitism rates are inversely correlated with density at most spatial scales. Functional responses are negative, inversely correlated with density.

Experiments demonstrate that *A. delicatus* oviposits independently of the host clutch size; female wasps find but shun many eggs in all but the smallest host clutches. All host eggs are desirable and distinguishable. Dispersal during oviposition spreads wasp progeny among host clutches and among sites. I posit that *A. delicatus* spreads risk to its progeny among sites. In north Florida, the major risk is winter cold, which frequently causes local extinction. Beach wrack and flotsam insulate a few patches of the host plant and provide refuges from which both planthoppers and parasitoids disperse throughout the marsh in spring.

COMMUNITY STRUCTURE IN LEAFHOPPERS AND PLANTHOPPERS. Peter Stiling, Department of Biological Science, Florida State University, Tallahassee, Florida 32306, U.S.A.

Studies on leafhopper and planthopper communities are reviewed. Evidence is presented on the frequency of interspecific competition between species. Some consideration is also given to the structure of parasite communities attacking *Auchenorrhyncha*.

PLANTHOPPER SPECIATION - THE ROLE OF ACOUSTIC SIGNALS. M.F. Claridge, Department of Zoology, University College, Cardiff, CF1 1XL, Wales, U.K.

Speciation can only be studied after the event. Related planthopper species usually differ both in host plant relations and in acoustic recognition signals. Undue concentration on host plant data and supposed biotypes, at the expense of species recognition systems may be misleading. Sympatric and allopatric models of speciation will be evaluated with respect to the evidence available for different planthoppers. Most examples are consistent with allopatric speciation.

MATING SYSTEMS AND INTRASPECIFIC INTERACTIONS IN PLANTHOPPERS. T. Ichikawa, Faculty of Agriculture, Kagawa University, Kita-gun, Kagawa 761-07, Japan.

When we attempt to clarify the mating systems of planthoppers, we must pay attention to their behavioral strategies to acquire mates in their specific populations which undergo temporal and spatial changes both in size and quality. Although investigated species are rather few, planthoppers are known to utilize vibration signals not only in finding and mating with conspecific mates in both sexes, but also in intraspecific male-male competitions. Therefore, it is important to know the circumstances utilizing the signals and substantial effects of the signals in their behaviors for understanding of their mating systems. Most species of planthoppers inhabit on graminaceous plants which usually offer temporally stable resources at most for several generations. Wing polymorphism of one or both sexes is known in many species living under such environments. Therefore, it is essential to clarify the mating strategies of brachypters and macropters for understanding the total features of mating systems in specific populations. Above mentioned approaches might throw light upon the evolution of wing polymorphism in planthoppers. The author will discuss on their mating systems mainly by dealing with the brown planthopper, *Nilaparvata lugens*, as an example.

GENETICS OF PLANTHOPPER-HOST PLANT INTERACTIONS. G.K. RODERICK, Department of Entomology, University of Maryland, College Park, Maryland 20742, USA.

For planthoppers in agricultural and natural systems, growing literatures exist concerning 1) genetics and 2) host plant utilization. Here, I review studies from both fields which illustrate characteristics of planthoppers and their host plants that theoretically will promote genetic variation for host plant utilization. Such characteristics include differential survival of genotypes on different host types, independent regulation of populations on different host types, decreased mobility among host types, assortative mating, and habitat selection. Existing evidence from both managed and natural systems suggests that much genetic variation exists in planthoppers and their host plants for host plant utilization as well as for resistance of host plants to planthoppers. Because of their small size, the ease at which they can be reared under controlled conditions, and their agricultural importance, planthoppers have a great potential for future genetic studies.

PLANTHOPPER TRANSMISSION OF PLANT PATHOGENS. L. R. Nault, Department of Entomology, Ohio Agricultural Research and Development Center, The Ohio State University, Wooster, OH 44691

Three families of planthoppers, the Delphacidae, Cixiidae, and the Flatidae, have species that are vectors of plant pathogens. The delphacids are vectors of 17 viruses, the cixiids of four mycoplasma-like organisms (MLO) and the flatid species, *Septhena cinerea*, transmits the fire blight bacterium in apples. The viruses vectored by delphacids are included in three virus groups, the Reoviridae (fijiviruses), rhabdoviruses and the tenuiviruses. These viruses have in common the ability to multiply in their vectors and to be transovarially passed from infective females to their offspring. The MLO's also propagate in their vectors but none are known to undergo transovarial passage. Possible mechanisms of vector specificity and the origin of these organisms as insect pathogens will be discussed.

APPLICATION OF SIMULATION MODELLING AND EXPERT SYSTEMS IN PLANTHOPPER MANAGEMENT. J.Cheng, Department of Plant Protection, Zhejiang Agricultural University, Hangzhou, Zhejiang, P.R.China.

As an organic link between ecology research and pest management, modelling techniques and expert systems can be utilized to improve the planthopper management through synthesizing ecological information and enhancing the perception of pest problems, e.g.

Finding out more economic and effective control measures with less side-effects on ecosystem by means of simulation screen and evaluation;

Deriving dynamic thresholds through simulation analysis of relations between pests and crops under different ecological conditions;

Developing desirable IPM strategy from testing various combinations of control measures with optimization methods;

Improving decision-making with an expert system containing new information.

The possible areas and procedures of application are summarized based on the analysis of management system.

MICROEVOLUTION AND GENE FLOW IN PLANTHOPPER POPULATIONS: APPLICATIONS TO THE DYNAMICS OF RESISTANCE IN CROPS. K.D. Gallagher*, K. Sogawa and P.E. Kenmore, International Rice Research Institute, P.O. Box 933 Manila, Philippines, Kyushu National Agricultural Experiment Station, Chikugo, Japan and FAO P.O. Box 1864 Manila, Philippines.

Studies of heritable characters in field populations of planthopper pests indicate that host-plant resistance developed by plantbreeders and deployed over large areas with varying indigenous populations exerted selection pressure to changes first within and consequently among these populations. Analyses of frequencies of phenotypes including adult longevity, fecundity, and honeydew excretion in Philippine and Indonesian *Nilaparvata lugens* (Stål) (Hom: Delphacidae) historically unable to survive on rice varieties with any host-plant resistance genes showed multiple adaptation to widely planted host resistance genes by individuals but low frequency of survival on recently introduced resistance genes. The contributions of gene flow and other selection forces such as natural enemies can be estimated. Methods and modelling to predict future adaptation to resistance genes in this and other crop systems should include field and laboratory techniques for measuring frequencies of adapted individuals within populations, comparisons among populations, and testable predictions of the direction and phenotypic frequencies.

THE IMPACT OF ECOLOGICAL RESEARCH ON THE MANAGEMENT OF PLANTHOPPER POPULATIONS. P.E. Kenmore and K.L. Heong, FAO P.O. Box 1864, Manila, Philippines and IRRI, P.O. Box 933, Manila, Philippines.

Planthoppers become pests when removed from natural controls, as new immigrants, in short cycle annual crops, and most often when insecticide misuse releases populations. Management depends on restoring natural control by conservation of indigenous natural enemies whose impact is best shown by insecticide check and cage studies. Practical conservation requires frequent field monitoring of the ratios of planthoppers, natural enemies and other pests, and selective insecticides. Crops within normal flight ambit form a mosaic of population sources and sinks. Inter-regional migration is best monitored with biometeorological tools. Host-plant nutritional quality and apparency can be altered by selection, planting dates, cropping pattern, and fertility. Strong location-specific interactions among population controls at different trophic levels mandate field studies to give best mixes of management tactics. Research is impotent to improve management unless there is strong farmer and extension participation, education, and feedback. The paper will emphasize cases from rice and sugarcane.

HOST SWITCHING AND SPECIATION IN *RHAGOLETIS* (DIPTERA: TEPHRITIDAE). G.L. Bush, Department of Zoology, Michigan State University, East Lansing, Michigan 48824.

Several species of *Rhagoletis* fruit flies have established genetically distinct populations on introduced host plants within the past 150 years. Host switching is known to have occurred sympatrically and the host races developed rapidly in the absence of geographic isolation. Electrophoretic genetic analysis of sympatric populations of *R. pomonella* apple and hawthorn host races indicates that they do not freely interbreed in nature. An important biological attribute of these flies that contributes to reproductive isolation between host races is that mating occurs only on the host plant. Behavior and electrophysiological studies of the host races and their hybrids indicates that host selection is under genetic control. A host shift, therefore, must involve changes in genes affecting host preference. A genetic computer simulation study modeling speciation by divergence in host preference for a sympatric distribution of two hosts demonstrates that considerable progress towards speciation readily occurs under biologically realistic conditions when mate choice is closely coupled with host preference as commonly occurs in many parasitic taxa. Sympatric speciation is thus a possible outcome of host shifts in *Rhagoletis* and other Tephritidae, and may account for the sympatric occurrence of many closely related stenophagous and monophagous species in this family of parasites.

THE *DACUS DORSALIS* COMPLEX IN S.E. ASIA. R.A.I. Drew (Australia)

No Abstract

POPULATION GENETICS OF MEDFLY. G. Gasperi*, A.R. Malacrida, L. Baruffi, R. Milani, Department of Animal Biology, University of Pavia, Pavia, Italy.

Gene frequency data from samples of *Ceratitis capitata* populations at different geographic areas, in the species-areal, were used to investigate spatial and temporal patterns in population structure. The samples were collected in Kenya (Africa), in Reunion Island and, for the Mediterranean area, in Sardinia (Italy) and in Procida (small island in front of Naples, Italy). Significant spatial heterogeneity in allele frequencies was observed on regional scale, in relation to the dispersion of the medfly from its geographic centre of origin (Africa) to the periphery (Mediterranean Regions). Populations from Kenya and Reunion were correlated with unique set of genes and they show high level of genetic differentiation in comparison with those from the Mediterranean regions. The samples of Procida, collected on different fruits, in different seasons for four years, provided consistent indications of seasonal changes and bottleneck effects.

LEARNING BEHAVIOR IN FRUIT FLIES. R.J. Prokopy* and D.R. Papaj, Department of Entomology, University of Massachusetts, Amherst, Massachusetts, 01003, U.S.A.

We have shown that adult apple maggot and Mediterranean fruit flies are capable of learning and remembering characteristics of host fruit upon which they have alighted and oviposited. Here, for apple maggot flies, we explore the effects of prior host fruit experience of females on components of habitat preference and of males on propensity to defend territories for acquiring mates. For both apple maggot and medfly females, we also explore the influence of prior experience with host plant foliage on fly behavior.

THE CONTRIBUTION OF TEPHRITID TAXONOMY TO NORTH AMERICAN WEED BIOCONTROL PROGRAMMES: I.M. White, CAB International Institute of Entomology, 56 Queen's Gate, London, SW7 5JR, UK.

The modern taxonomist (or biosystematist) working on potential weed biocontrol agents tries to combine taxonomic revision with field and collection surveys to produce accurate host and distribution lists. Knowing the host preferences of tephritid species (and sometimes populations) in different areas, enables the weed biocontrol specialist to select the best area in which to search for a potential control agent. In the past, inaccurate taxonomy has led to the production of erroneous host lists, which have hindered biocontrol programmes. Inaccurate distribution data and poor taxonomic precision have also caused problems. In one case two similar looking *Urophora* species which attack *Centaurea solstitialis* in different parts of Europe were confused; however, only one of these is able to develop on North American *C. solstitialis* plants. No one had this information at the time a biocontrol agent was first sought and the wrong *Urophora* species was introduced into the USA through no fault of the weed biocontrol specialists involved.

BACTERIAL RELATIONSHIPS IN MEDFLY AND OLIVE FLY. V. Girolami, Department of Plant Protection, University of Udine, 33100 Udine, Italy.

The olive fly (*Dacus oleae* Gmelin) and the medfly (*Ceratitis capitata* Wied.) present very different symbiotic association among Tephritidae. The main morphological differences are: the shape and size of the pharyngeal bulbs, the shape of "membranous bodies" inside the peritrophic membrane and the larval blind sacs shape, which are full of bacteria only in the olive fly.

The olive fly bacteria do not multiply in vitro and seem highly specific and are transmitted hereditarily.

The medfly bacteria are easy to cultivate and it appears that they can be both hereditarily transmitted and acquired from the environment.

The significance of the symbiosis is discussed.

THE SIGNIFICANCE OF LEKKING BEHAVIOR IN TEPHRITID FRUIT FLIES. C.O. Calkins, USDA/ARS, 1700 S.W. 23rd Drive, Gainesville, Florida 32604, USA.

The mating strategy employed by several tropical and subtropical tephritid fruit flies is a male aggregation system referred to as a lek. In the tropics where host fruit appear randomly in space and time, males are not able to dominate a resource in exchange for a mating opportunity. Thus, males are forced to advertize their degree of fitness in order to attract females. Females have the opportunity to compare the fitness of prospective mates while visiting such aggregations of males and to select the male that most nearly satisfies their criteria. The effect of this female choice on the evolution of the mating systems are discussed.

FEEDING AND DIETARY REQUIREMENTS OF FRUIT FLIES (DIPTERA: TEPHRITIDAE). G.J. Tsiropoulos, Institute of Biology, N.R.C.P.S., Athens 153 10, Greece

Studies on the dietary requirements of several fruit fly species, have shown that the specific adult needs vary among species, forming a "dietary spectrum". This is the result of differences in the quantity and quality of metabolites transferred, from the larval to the adult stage. Thus, some species are able to survive and reproduce on "minimal" diets, containing water and a carbohydrate only, while at the other end of the spectrum are species requiring "complete" diets, containing, besides water and a carbohydrate, amino acids, vitamins, minerals and a sterol. In nature, all necessary metabolites are coming from natural food sources, such as honeydews, nectars, fruit juices, pollens and others. Tephritids when deprived of food and/or water, initiate flights to discover new locales rich in nutritional elements. All feeding responses involve some underlying nutritional component(s), acting either as phagostimulants or as phagodeterrents, which produce, positive or negative sensory feedbacks respectively. The complex amount of positive and negative information is ultimately integrated in the fly's central nervous system, to produce the appropriate final motor output.

REGULATION OF DIAPAUSE IN RHAGOLETIS FLIES (DIPTERA: TEPHRITIDAE). M.T. ALINIAZEE, DEPARTMENT OF ENTOMOLOGY, OREGON STATE UNIVERSITY, CORVALLIS, OREGON 97331.

Diapause in *Rhagoletis* flies is generally regulated by the genetic makeup of the species and various components of the external environment. In some species such as *R. indifferens* and *R. fausta*, the environmental factors have relatively little impact on diapause induction while the same factors appear to play a major role in diapause induction of other species, i.e. *R. zephyria*, *R. pomonella* and *R. completa*. Diapause termination is generally governed by the rate of diapause maturation (development) and the onset of warmer temperatures during the post-diapause development phase.

A large degree of variation exists among the different *Rhagoletis* species in their diapause induction, expression, maturation (development) and termination modalities.

DEMOGRAPHY OF PEST TEPHRITIDS. J.R. Carey*, Department of Entomology, University of California, Davis, CA 95616 USA.

Although it has been known for decades that many pest tephritids lay enormous numbers of eggs, live an extraordinarily long time and are capable of being mass reared, only in recent years have tephritid management and ecological problems been systematically viewed in a demographic context. The objective of this paper is to review advances in demographic analysis of tephritid species in basically 3 areas: i) cohort analysis--survival, female reproduction, clutch relations and analysis of male quality; ii) population analysis--application of conventional Lotka, two-sex and 'birth type' models to fruit fly problems; and iii) mass rearing models--single species and parasitoid rearing. Comparative aspects within and between species will be stressed.

POPULATION DYNAMICS OF DACINE FRUIT FLIES. B.S. Fletcher, CSIRO, Division of Entomology, G.P.O. Box 1700, Canberra, A.C.T. 2601 Australia

Almost all Dacine fruit flies utilize ripening fruit as larval hosts. The population dynamics of the polyphagous multivoltine species which have hosts available more or less continuously throughout the year is largely determined by the survival and development rates of the different life stages and fecundity of females. Natural enemies appear to be of little importance in regulating numbers and intra-specific competition only acts at relatively high population levels when host availability can become a limiting resource. In monophagous and stenophagous species host phenology and abundance has a major influence on their population dynamics.

DYNAMICS AND LIFE HISTORY PATTERNS OF THE MED-FLY, *CERATITIS CAPITATA* (WIEDEMANN), POPULATIONS IN HAWAII. N. J. Liquido*, R. T. Cunningham, and S. Nakagawa. USDA-ARS, P. O. Box 4459, Hilo, Hawaii 96720 U.S.A.

The host resource utilization, spatial distribution, and life history patterns of the medfly were studied at elevations ranging from 100 to 9200 ft. on the islands of Hawaii and Maui. Out of 209 host plant species studied at 321 sites, only 66 proved to be suitable hosts of the medfly. Determinant host species vary with sites.

Because of the probable competitive exclusion between the medfly and the oriental fruit fly, *Dacus dorsalis* Hendel the spatial distribution of the medfly at different elevations were analyzed in relation to that of the oriental fruit fly. Medflies were virtually not existing in lower elevations, but dominated the oriental fruit flies at higher elevations. Medflies and oriental fruit flies coexist in the same host fruits in several sites.

The life history statistics measured were duration and survivorship of egg, larval, pupal, and adult stages. Medflies were tolerant of lower temperature and relative humidity associated with higher elevations.

POTENTIAL USE OF CERTAIN JUVENOIDS AS MORPHOGENETIC AND PROGENY SUPPRESSANTS AGAINST MEDFLY: LABORATORY ASSESSMENTS AND FUTURE PROSPECTS. M.T. El-Ibrashy, Laboratory of Plant Protection, National Research Centre, Dokki, Cairo, Egypt.

Of twelve novel juvenoids reported to be technically readily accessible and expected to have reasonable stability under practical situations, only a few have proved highly potent to seriously derange metamorphosis and/or reproduction of the medfly when topically administered to "white prepupae".

Surprisingly, larval-like creatures and eclosing adults retaining pupal heads were frequently encountered among numerous others assuming a wide array of morphological anomalies, most of which have not previously been demonstrated in cyclorrhaphous Diptera.

Apart from the basic importance of the findings obtained particularly for those who are interested in studying endocrine regulation of differentiation in the Cyclorrhapha at the molecular level, prospective use of such juvenoids is discussed in view of the context of "holistic" integrated pest management of the whole pest complex in a given fruit growing biocenosis.

DEVELOPMENTS IN THE FORMULATION AND APPLICATION OF BAIT SPRAYS. R.T. Cunningham*, N. Wakabayashi, and H. Chan, U.S. Department of Agriculture, Agricultural Research Service, Hilo, Hawaii 96720.

The proteinaceous food baits have proven to be a very useful tool for survey trapping, for localized field control, and for eradication programs directed against tropical tephritid fruit flies. However, an understanding of the basis for the attractive properties of these products of protein degradation has proven to be elusive. Ammonia has long been recognized as an attractant and recent work in several laboratories has focused on its role in proteinaceous baits. Work in our laboratory has shown that ammonia has differential effects among three species of pest tephritids in Hawaii and is dependent upon concentration. But it is obvious that ammonia alone does not account for the degree of attraction observed with proteinaceous baits. Although proteinaceous baits are complex mixtures of over 100 volatile compounds their level of attraction can be approached by using mixtures of less than a dozen by-products of protein degradation. Our collaborative work is directed at exploring those oligo-component, defined mixtures as synergists with ammonia with the idea that through manipulation of concentrations and components we may be able to greatly enhance the attraction of baits.

THE STERILE INSECT TECHNIQUE AGAINST FRUIT FLIES: RECENT ADVANCES AND FUTURE DEVELOPMENTS. D.A. Lindquist and A.P. Economopoulos*, International Atomic Energy Agency, P.O. Box 200, A-1400, Vienna, Austria.

Tephritid fruit flies cause extensive damage to fruit and vegetables in many parts of the world. The development and application of the Sterile Insect Technique (SIT) against a number of these fruit fly species offers the possibility of eradication or control, depending upon circumstances. Recent advances and potential future developments in using the SIT against Tephritid fruit flies will be discussed. Included will be a review of current practical fruit fly control/eradication programmes utilizing the SIT, status of developing genetic sexing strains so that males only can be released, improvements in mass-rearing technology, potential for new and improved attractants to be used in conjunction with the SIT, and quality control procedures in the mass-production of fruit flies.

THE PLANNING AND IMPLEMENTATION OF ACTION PLANS FOR EXOTIC FRUIT FLIES IN THE UNITED STATES. Jeffrey N.L. Stibick, United States Department of Agriculture, Animal and Plant Health Inspection Service, Hyattsville, Maryland 20782, USA.

A brief history leading to the rationale for action plans is presented. Some of the early concepts are discussed. The development of an action plan is given, starting from pest selection, literature search, outline, identification of experts, drafts prepared and reviewed, committee formation, final review, and publication. Stress is laid on continuing review and updating of plans with state-of-the-art technology. The basic structure of fruit fly action plans will be discussed, including authorization, general information, survey, regulatory, eradication, and the addenda. Special items relating to fruit fly plans are presented, including the redraft and expansion of the Medfly plan to serve as a manual for other fruit fly plans or as a source of technical data. Finally, the implementation of an action plan will be given, starting with a find, State/Federal meetings, how an action plan serves as the base for State/Federal meetings agreement, and how modifications may be made in an actual operation.

STATUS OF THE FRUIT FLY ERADICATION PROGRAMS IN OKINAWA AGAINST *DACUS DORSALIS* AND *D. CUCURBITAE*. H. Kuba*, H. Kakinohana and H. Nakamori, Fruit Fly Eradication Project Office, Okinawa Prefectural Government, 123 Maji, Naha 902, Japan.

The Oriental fruit fly, *Dacus dorsalis*, and the melon fly, *D. cucurbitae*, were first discovered in Okinawa in 1919, and spread to all of the South-West Islands. The eradication program of the Oriental fruit fly in Okinawa Prefecture (225,000ha) was started in 1977 using the Male Annihilation Method. We distributed ample amounts of fiber board squares (4.5x4.5x0.9cm) impregnated with 10g of 75-80% methyl-eugenol and 3.5-4.0% BRP in the target area. In 1986, we eradicated the Oriental fruit fly in the entire Okinawa Prefecture.

An experimental melon fly eradication program in Kume Island (5,850ha) was started in 1972 using the Sterile Insect Technique. Following the successful eradication in Kume Island, the melon fly eradication program for the entire Okinawa Prefecture was initiated in 1979. The melon fly mass-rearing facility capable of rearing 200 million pupae per week was constructed. Sterile fly releases by helicopter began in the Miyako islands (22,700ha) in August 1984 and in the Okinawa islands (144,200ha) in August 1986. Declaration of melon fly eradication was issued by National Government for the Miyako islands in November 1987.

BIOLOGICAL CONTROL OF WEEDS WITH TEPHRITIDAE. P. Harris, Research Station, Agriculture Canada, Regina, Saskatchewan Canada, S4P 3A2.

Seventeen species of tephritids have been used for biocontrol of weeds of which 2/3 cause major damage to their host. All but two of the weeds are composites reflecting the abundance of tephritids on this family. Their specificity, which is partly dictated by oviposition requirements, makes them attractive for biocontrol. Several tephritid species may coexist in thistle capitula but the greatest energy loss is from gall inducing species that attack at any early bud stage. In these species males produce an aggregation pheromone, the flies live up to a month on unfermented honey (less on honey-yeast), lack adult symbionts and tend to form local races. Tephritids that attack later tend to lack aggregation pheromones but mark attacked capitula, disperse more widely, contain adult symbionts and live up to 4 months on honey-yeast. Several tephritids do more damage to the weed than a single species. Wing patterns, courtship displays and host plants may be less important for maintaining species integrity than supposed.

THE CURRENT FRUIT FLY ERADICATION PROJECT: CURRENT AND FUTURE PLANS. J. E. Gilmore, USDA/ARS, Tropical Fruit & Veg. Res. Lab, P. O. Box 2280, Honolulu, HI 96804.

Eradiation of the Hawaiian tephritid fruit fly complex consisting of Ceratitis capitata (Wiedemann), Dacus dorsalis Hendel, and D. cucurbitae Coquillett, plus a recently introduced species, D. latifrons (Hendel), is a longstanding goal that offers great potential benefits to agriculture both in the state of Hawaii and the U.S. mainland. Elimination of these tephritids from Hawaii would provide opportunities for expansion and diversification of agriculture in the state and would eliminate a significant reservoir for potential introduction to the U.S. mainland.

The recommended strategy for eradication involves a sequential approach, a single species at a time, but on a state-wide basis utilizing the male annihilation and SIT approaches, complemented by parasite augmentation if the latter proves effective in pilot studies currently underway.

A pilot test on the island of Kauai has been identified as a need to demonstrate eradication with the available technology and to address a number of environmental concerns relative to the application of the male annihilation treatments. Implementation of the pilot test is contingent upon availability of funding.

PROGRESS OF THE MEDFLY ERADICATION PROGRAM IN MEXICO, GUATEMALA AND CENTRAL AMERICA. Reyes, F. Hentz, G. Ortiz, A. Schwarz & J. Hendrichs* (Mexico)

No Abstract

FRUIT FLY ERADICATION: PROBLEMS APPROACHES AND POSSIBILITIES AT THE HABITAT LEVEL. E. J. Harris, USDA/ARS, Tropical Fruit and Veg. Res. Lab., P. O. Box 2280, Honolulu, HI 96804.

The difficulty or ease of achieving tephritid fruit fly eradication is related to habitat conditions and the influence of the habitat on fruit fly populations. Data on fruit fly population parameters obtained under different habitat conditions are presented and discussed in regard to the problems, the approaches, and possible strategies for fruit fly eradication.

WELCOME AND OPENING REMARKS. R.D. Eikenbary & P.E. Richardson, Department of Entomology, Oklahoma State University, Stillwater, Oklahoma, 74078-0464, USA.

We have assembled a distinguished and scholarly group of scientists interested in aphids or organisms with which they interact. This should be a very interesting and timely symposium designed to integrate knowledge from all levels surrounding the interesting and important organisms which are aphids. It should also benefit from the synergy of bringing together both world renowned and lesser known authors from throughout the world to commingle unique perspectives.

ECOLOGICAL INTERACTIONS OF APHIDS AND THEIR HOST PLANTS: A.F.G. DIXON, School of Biological Sciences, University of East Anglia, Norwich, NR4 7JT, U.K.

Aphids are opportunists. In addition, parthenogenesis and feeding on phloem sap, which both developed early in the evolution of aphids, have been major factors affecting their ecology. This paper considers how these factors have interacted to determine the reproductive potential and size of aphids, their pest status, and low species diversity. Such an approach reveals the importance of the constraints imposed by their way of life.

APHID/HOST PLANT ECOLOGY: THE BIRD CHERRY-OAT APHID AS A MODEL. J. Pettersson, S. Wiktelius and J. Weibull*, Department of Plant and Forest Protection, Swedish University of Agricultural Sciences, P.O. Box 7044, S-750 07 Uppsala, Sweden.

The aphid *Rhopalosiphum padi* (L.) (Homoptera: Aphididae) is holocyclic in Sweden and has a wide range of graminaceous secondary hosts. The species is one of the most important pests in spring cereals. This paper summarizes several years of lab and field investigations concerning *R. padi*.

Various aspects of the aphid-plant relationships are discussed on the basis of its life cycle. These include:

- colonisation of the secondary hosts, settling behaviour and host plant choice;
- plant and aphid phenology, modelling and aphid performance in relation to plant quality, and
- migration patterns.

EXPERIMENTAL STUDIES ON SOME APHID LIFE-CYCLE PATTERNS. Zhang Guang-Xue, Institute of Zoology, Academia Sinica.

This paper deals with the life-cycle patterns of some species of aphids, with special reference to the variation of the life-cycle patterns of the cotton aphid as well as the hybridization between the cotton aphid and the soybean aphid. Based upon results obtained in these experiments, a review of Mordvilko's theory is given.

By means of artificial transplantation between plant hosts, it was found that the cotton aphids possess three life-cycle patterns:

A. Anholocyclic life-cycle may be divided again into two subpatterns.

Microclimatic conditions played an important role in influencing the life-cycle pattern of the aphid, which proposition is contrary to Mordvilko's theory.

B. Heteroecious holocyclic life-cycle which may be divided into three subpatterns; based the quite different kinds of primary host plants: a) *Zanthoxylum similans* b) *Rhamnus* spp., c) *Punica granatum*.

C. Autoecious holocyclic life-cycle—The primary host plant is *Hibiscus syriacus*, and the secondary one is cotton.

The soybean aphid, *Aphis glycines* Matsumura is of the heteroecious holocyclic life-cycle pattern. Its primary hosts are *Rhamnus* spp. and the secondary host is *Glycine max*. It is found that the interspecific crosses between *A. gossypii* and *A. glycines* may occasionally occur in both natural and artificial conditions. Its hybrid offsprings reproduce parthenogenetic and sexual forms to complete the life-cycle.

Based on the history of plant hosts, *Rhamnus* developed much later than *Zanthoxylum*. It may be assumed that the former was a secondary host of the cotton aphid and then gradually evolved to become its primary host.

THE POPULATION BIOLOGICAL CONSEQUENCES OF A MOSAIC-LIKE POPULATION STRUCTURE IN *MACROSIPHUM ROSAE*. *Klaus Wöhrmann and Jürgen Tomiuk. Institute of Biology II, University of Tübingen, 7400 Tübingen, FRG.

The genetic heterogeneity within and between subunits of European populations of *Macrosiphum rosae* is analysed by methods of Nei and Chesser (1983). The analysis is based on data of two enzyme systems (MDH, PGM), and reveals that 56.35% of the total genetic variability is realized within one rose plant. A further 9.36% is contributed by plants within one rose bed. Little heterogeneity is added by higher subunits such as rose beds within a subpopulation (1.75%), subpopulations (3.51%) and populations within one region (3.02%). However, the regions themselves contribute 26%. The results are discussed with respect to the importance of drift, migration, selection and recombination in determining the overall genetic structure of the population.

THE ECOLOGICAL DYNAMICS OF APHID BIOTYPES AND THEIR PREDATORS IN MIXTURES OF PLANT GENOTYPES. L. R. Wilhoit, Division of Biological Control, University of California, Berkeley, CA 94720.

Herbivorous insects often overcome new host defenses within a few years by evolving new biotypes, frustrating the efforts of plant breeders in developing resistant crop varieties. Crop variety mixtures containing susceptible varieties could slow the evolution of such resistance-overcoming biotypes. This is explained for aphids through stochastic population models. The susceptible plants within a field allow the growth of the predominant biotype and its predators. The presence of these predators will keep in check the population of any later arriving resistant-overcoming biotypes. These ideas have been tested in field experiments with the greenbug, *Schizaphis graminum*. Also, understanding the evolution of biotypes requires an understanding of the nature of genetic variation in aphid populations. Experiments have shown that much variation exists in greenbug populations, more than is indicated by standard biotype labels. Such knowledge is needed to determine the types of varieties that should be included in variety mixtures.

PLANT HYBRID ZONES AS "GENETIC SINKS" FOR THE GALL APHID, PEMPHIGUS BETAE. Thomas G. Whitham, Department of Biological Sciences, Northern Arizona University, Flagstaff, AZ 86011

Narrowleaf cottonwood, Populus angustifolia hybridizes over a 13 km zone with Fremont cottonwood, P. fremontii. The center of the distribution of the gall aphid, Pemphigus betae is the hybrid zone of its host species where it exists at densities 100+ times greater than in the pure host zones. Transfer experiments show that these hybrid trees are more susceptible to aphids than the pure host species. Less than 3% of the host population supports >75% of all surviving aphids and their progeny. These results have basic and applied implications in that susceptible host genotypes may serve as "genetic sinks" preventing aphid adaptation to the rest of the host population.

THE USE OF RESTRICTION FRAGMENT LENGTH POLYMORPHISMS TO STUDY THE ECOLOGICAL GENETICS OF APHID-PLANT INTERACTIONS. T.G. Whitham, K.N. Paige*, and P. Keim, Department of Biology, Northern Arizona University, Flagstaff, Arizona 86011; Department of Biology, University of Utah, Salt Lake City, Utah 84112; Department of Genetics, Iowa State University, Ames, Iowa 50011.

RFLP (restriction fragment length polymorphism) analysis represents a powerful tool for examining the ecological genetics of plant-herbivore interactions. RFLP's can be used, for example, to study coevolutionary interactions between plants and herbivores, the genetic basis of host-plant resistance to herbivore attack and the distribution of herbivores in relation to host-plant genotype. Discussions will center on the use of RFLP's in obtaining precise genotypic information, marking genes for resistance and screening plants for susceptibility to parasite attack. The use of this technique is exemplified by our studies of the interaction between a gall forming aphid, Pemphigus betae, and its host, Populus sp.

CONTINUOUS RECORDING OF STYLET PENETRATION ACTIVITIES BY APHIDS. W.F. Tjallingii. Department of Entomology, Agricultural University, POB 8031, 6700 EH Wageningen, The Netherlands.

Plant penetration by aphid stylets can be recorded by making the insect part of an electrical circuit. The aphid, which is connected by a thin gold wire glued on the dorsum, completes the circuit when its stylets penetrate the plant which is connected by a lead in the soil or water. The recorded voltage changes, referred to as the electrical penetration graph (EPG), appeared to reflect events in or near the ends of the stylets' capillary canals. Six different EPG patterns have been distinguished and correlated experimentally with either aphid activities or tissue positions of the stylet tip in the plant. Although a certain aphid activity is not necessarily implying a particular tissue position and vice versa, some activities seem to occur in only one or a few tissue positions. When stylets were amputated during EPG recording sap exudation from severed stylets could be observed in some cases, and the tissue with the inserted stylets was processed for electron microscopy. Thus, stylet tip positions unto subcellular level were correlated with EPG wave-forms at the moment of amputation. Also, the preceeding pathway of the stylets in the plant tissue was studied.

APHID STYLET MIGRATION AND HOST PLANT REACTION IN THE CASE OF ADELGIDAE ON SPRUCE. O. ROHRITSCH, Laboratoire de Cécidologie, UA 1182 CNRS-ULP, Institut de Botanique, 67083 STRASBOURG Cedex FRANCE

The Adelgidae (conifer woolly aphids) induce galls on spruce (Picea sp.). With the example of Adelges abietis L. and Adelges laricis V., both insects attacking the bud of Picea excelsa L. at the same moment, the problem of gall specificity is discussed.

The Adelgidae are parenchyma feeders, the path of the very long mouth parts, the stylets, is always intercellular and is easily traced owing to the salivary sheaths which the aphid secretes in the plant tissue. The probing and feeding behavior of the aphid can be easily localized and followed with a simple technique applied on hand cut sections.

It is possible to demonstrate a very specific pattern of salivary track distribution by each species in the spruce tissue. By puncturing the cells (without cell rupture), by causing partial dissolution of the middle lamella and modification in the cell wall, the first instar larva induces a wound reaction on cells along the stylet tracks. Through the "irritating" action cells are withdrawn from the normal growth pattern and engaged in gall growth in competition with normal meristematic growth.

It is easy to understand the importance of the localization of these cells along the shoot axis. Their influence will be different if localized at the base of a vigorous fast growing shoot (A. abietis) or in the center of a small slowly developing one (A. laricis). The sheath distribution pattern in space and time translates the cell stimulation pattern which is responsible for specific gall structure.

RESISTANCE MECHANISMS OF PLANT GENOTYPES TO DIFFERENT APHID SPECIES. P. Harrewijn, Research Institute for Plant Protection, P.O. Box 9060, 6700 GW Wageningen, the Netherlands.

Different resistance mechanisms of plants to aphids operate during the attack phase, during walking and probing, during the penetration phase towards the phloem, during tapping the phloem and after prolonged ingestion of food. Olfactory stimuli appear to facilitate the choice between hosts and non-hosts (odour-conditioned anemotaxis in Cryptomyzus korschelti and Rhopalosiphum padi). Even on host plants aphids do not easily trace the phloem: on non-hosts insertion of the stylets can be more difficult or even interrupted before the phloem is reached. This can be due to the composition of plant matrix polysaccharides or allelochemicals encountered when sampling mesophyll cells.

Although a number of allelochemicals were reported to have antibiotic or antixenotic effects during probing and ingestion, substantially more evidence is needed to attribute aphid resistance to the presence of these substances, especially when the phloem is involved. Resistance of oats to R. padi appears to be mainly based upon imbalance of amino acids in the phloem, whereas Naso-novia ribisnigri both finds and leaves the phloem of a highly resistant lettuce selection in a very short time.

ROLE OF DIFFERENTIAL FEEDING BEHAVIOR AND PLANT RESPONSE IN THE SUBGENUS ABSINTHAPHIS (HOMOPTERA: APHIDIDAE). M.P. Mier Durante* and J.M. Nieto Nafria*, Departamento de Biología Animal, Facultad de Biología, Universidad de León, E-24071 León, Spain.

Eight species are included in the subgenus Absinthaphis: Aphis (Ab.) alba, A. (Ab.) cinnae, A. (Ab.) hirsuta, A. (Ab.) hortobagyi, A. (Ab.) judenkoi, A. (Ab.) koraiensis, A. (Ab.) pannonica and A. (Ab.) thasevella, and another new species recorded in Spain, which are described here.

These species are monoecious on Artemisia spp. (8) and Helichrysum sp. (1). The diagnostic anatomical characteristics of the subgenus are related to those mentioned host-plants and with the response to aphids' actions (shape and size of the ultimate rostral segment, tarsus, cauda and siphunculi, chaetotaxy, etc.).

Some of these characteristics could be considered biotypical and they are similar to species characteristics of other genera living on species of the same Compositae group. However other are fully or in part absent on other species of subgenus Aphis, which live on the same plants.

APHID SALIVARY SECRETIONS AND PLANT TOXICOSES.

P.W. Miles, Entomology Department, Waite Agricultural Research Institute, University of Adelaide, Glen Osmond, South Australia 5064.

Aphididae typically have a specialized feeding process that causes minimal responses in their host plants: Intercellular penetration and uptake of food from phloem vessels rather than nucleated cells causes relatively little damage and/or necrosis. The salivary secretions subserve this specialization: The lipoprotein 'stylet sheath' seals abrasions, plugs wounds and is probably involved in the conversion of substances potentially toxic to plant and/or insect to inert, insoluble end products; there is evidence that the polyphenol oxidase secreted along with the sheath and in the 'watery saliva' may also subserve detoxification; such hydrolytic enzymes as occur in the 'watery saliva' appear to ease penetration of the midlamella. Deviation from this system, whether innate or caused by environmental circumstances and/or human intervention tends to bring about an increased response by the plant. Other Aphidoidea, in contrast, typically feed on parenchyma causing more cellular damage, thereby initiating far more specific and easily recognizable interactions between plant and insect.

THE ROLE OF PLANT MATRIX POLYSACCHARIDES IN APHID-PLANT INTERACTIONS. B.C. Campbell* and D.L. Dreyer, Western Regional Research Center, USDA-ARS, 800 Buchanan St., Albany, CA 94710, USA.

Aphids possess flexible, stylet-like mouthparts which enable them to surgically probe through a variety of plant tissues. During this process of probing, the aphid must use chemical cues within the plant to determine: a) if indeed the plant is a host-plant, b) the quality of the host-plant, c) the location of the stylet-tips within the plant or particular plant tissue and d) in which direction to continue probing to eventually reach the phloem. Many aphids use their stylets to probe intercellularly through the mesophyll parenchyma of their host-plant. In other cases the stylets may penetrate the cell wall, but they are either withdrawn shortly after penetration or they proceed through the cell, generally staying close to the interior aspect of the cell wall. By probing through the plant in this fashion the aphid avoids the toxic constituents (*e.g.*, phenolics) usually compartmentalized in vacuoles of mesophyll cells. In order to perform this mode of feeding behavior, aphids possess an array of enzymes (*viz.*, polysaccharases and carbohydrases) that enable them to breakdown a wide variety of plant hetero- and/or β -linked polysaccharides (*e.g.*, pectins, hemicelluloses, *etc.*) associated with the intercellular-cell wall matrix. Aphid-host plant compatibility is directly related to the rate at which these enzymes can depolymerize their respective polysaccharide substrates. Furthermore, the breakdown products of these matrix polysaccharides can act as chemical cues to the aphid. Alterations in the structure of these matrix polysaccharides result in a reduction in the rate of their depolymerization by enzymes in the existing biotype of aphid. This reduced rate of depolymerization is characteristic of host-plant resistance towards aphids and can trigger biotype formation. New biotypes of aphids possess new polysaccharases able to breakdown the altered substrate(s). The prospective role of aphid endosymbionts in the biosynthesis of these enzymes and their concomitant role in biotype formation are discussed.

GREENBUGS AND WHEAT: A MODEL SYSTEM FOR THE STUDY OF PHYTOTOXIC HOMOPTERA. James D. Ryan*, R. C. Johnson, A. J. Mort, and R. D. Eikenbary, Depts. of Agronomy, Biochemistry, and Entomology, Oklahoma State University

The greenbug (*Schizaphis graminum*) is an aphid capable of inducing severe chlorosis and necrosis in graminaceous hosts. Through the use of different greenbug biotypes and differentially responding near-isogenic lines, we have begun to understand several aspects of the physiological, behavioral, and molecular components of the greenbug/wheat interaction: i. After a 5 day greenbug infestation, susceptible plants showed increased membrane leakage, decreased carbon assimilation rate (A), transpiration (E), stomatal conductance to water vapor (gs), total chlorophyll, and rubisco activity. Intercellular CO₂ concentration (Ci) was unchanged. A vs Ci curves for infested and noninfested plants showed that there was no increased stomatal limitation to A associated with greenbug damage. After 1 hour of feeding, ultrastructural studies showed an increase in the size and number of plastoglobuli in the chloroplasts of susceptible plants along with the appearance of wall appositions in these cells after 2 days. No such effects were seen on resistant plants. ii. Electronically monitored feeding behavior showed that greenbugs fed normally on both susceptible and resistant wheat but delayed accepting the phloem on resistant plants. Resistant plants do not escape injury by altering greenbug feeding behavior. iii. Near-isogenic lines of wheat differing in the presence or absence of greenbug resistance genes are significantly different in the quantity and quality of cell wall pectic polysaccharides.

THE ROLE OF SECONDARY PLANT COMPOUNDS IN APHID-HOST INTERACTIONS. Hermann M. Niemeyer, Facultad de Ciencias, Universidad de Chile, Casilla 653, Santiago, Chile.

Several conditions should be fulfilled in order to implicate a secondary plant compound in plant-aphid interactions, for instance, varietal resistance related to concentration of the compound in the plant, encounter or ingestion of the compound by the aphid, relationship between biological activity of the compound in the plant and in a synthetic diet, biochemical and chemical mechanisms accounting for the compound's biological activity.

These conditions will be discussed using several case studies, with particular emphasis on hydroxamic acids from the Gramineae.

LIPIDS AT THE APHID-PLANT GENOMIC INTERFACE.

J.W. Dillwith, Department of Entomology, Oklahoma State University, Stillwater, Oklahoma, 74078 U.S.A.

Epicuticular hydrocarbons of aphids and their host plants are in most cases similar but not identical and consist of mixtures of n-alkanes with chain lengths from 25 to 37 carbons. Aphids do not obtain their cuticular hydrocarbons from the host plant but rather carry out *de novo* biosynthesis of these compounds. The cuticular hydrocarbon profile of each species is distinct, however biotypes of the greenbug, *Schizaphis graminum*, can be distinguished by characteristic n-alkane profiles.

It has been suggested that aphids may recognize host plants by sensing the composition and/or morphology of plant cuticular lipids. Studies with alfalfa have shown that the chemical composition and morphology of the surface lipids is quite different on different plant parts. The spotted alfalfa aphid, *Therioaphis maculata*, prefers to feed on leaves which are covered by wax with a high proportion of triacontanol and triacontanal. Stems and petioles which lack the alcohol and aldehyde are not preferred feeding sites. The feeding site preference of other insects on alfalfa also correlates with the chemical composition of the wax on various plant parts.

APHID MODIFICATION OF HOST PLANT NITROGEN METABOLISM.

K. W. Dorschner, Department of Plant, Soil, and Entomological Sciences, University of Idaho, Southwest Idaho Research and Extension Center, Parma, Idaho 83660.

Most aphids utilize the relatively nitrogen-poor phloem sap of their host plants as a primary food source. To compensate for this deficiency, aphids ingest tremendous quantities of phloem sap and tend to extract nitrogenous compounds from this sap in a very efficient manner. Some aphids can also enhance phloem sap nutritional quality by altering the nitrogen metabolism of their host leading to more successful aphid survival and reproduction. Instances and evidence of this behavior will be discussed as will the mechanisms employed where understood.

APHID BIOTYPES IN RELATION TO PLANT GENOTYPES AND CHEMICALLY DEFINED DIETS. J.L. Auclair and P.N. Srivastava*, Department of Biological Sciences, University of Montreal, Montreal, Quebec, Canada H3C 3J7.

Biotypes are defined as individuals of equal genotype. In aphids at least, equal genotype means behaving similarly as far as the researcher's immediate interests are concerned. On the basis of a biological function such as the ability to transmit virus, performance on different host-plants and on holidic diets, susceptibility to insecticides, feeding behaviour, differences in the components of pectinases, reaction to light etc., aphids have been characterized into many biotypes. A review is presented from the literature and from experiments carried out in our laboratory, during the last decade, on feeding behaviour and nutrition of pea aphid biotypes. Possible differences in nutritional requirements, for example amino acids and vitamins, that exist between aphid biotypes are examined. Some aspects of host-plant resistance in relation to biotypes are also discussed.

GENETIC VARIATION IN APHIDS IN RELATION TO HOST PLANT SPECIFICITY. R.L. Blackman, Department of Entomology, British Museum (Natural History), Cromwell Road, London, SW7 5BD, U.K.

Patterns of aphid-host plant specificity in natural environments will be compared with pest/crop systems, and the genetic determinants of such patterns will be discussed, especially in relation to the significance of life-cycle variation. How can host plant-associated variation in aphids be recognised and interpreted, how should it be treated taxonomically, and what is its relevance to pest management? Answers to these questions will be sought by considering recent work on several different pest species and species-complexes, including *Myzus persicae* and *Rhopalosiphum maidis*.

GENETIC STABILITY IN PARTHENOGENETIC APHID CLONES AND ITS IMPLICATIONS FOR HOST PLANT INTERACTIONS. J. Tomiuk, Institute of Biology II, Population Genetics, Auf der Morgenstelle 28, 7400 Tübingen, Federal Republic of Germany.

In lineages of aphid clones segregation at enzyme loci is rarely found which also indicates the stability of gene complexes coding for quantitative traits. Comparative studies in rose aphids have shown low variability and selective neutrality of enzyme loci, whereas interactions have been observed between clonal reproductive rates, body colour, host plants, and endoparasitism. The conclusions are that significant differences in clonal reproductive success rapidly result in host specialisation, and hitchhiking reduces the total genetic heterogeneity. Selection theory then predicts low flexibility to changing environments. But aphids have large morphological variation within clones which is highly adapted to conditions experienced every year. Therefore, in aphids intracolonial regulatory mechanisms are of a more evolutionary importance than polymorphism at individual loci coded by structural genes.

SEXUAL REPRODUCTION AND BIOTYPE INHERITANCE IN THE GREENBUG, *SCHIZAPHIS GRAMINUM*. G.J. Puterka* & D.C. Peters, Department of Entomology, Oklahoma State University, Stillwater, Oklahoma, USA 74078.

Sexual reproduction facilitates genetic recombination in greenbug populations and is the most likely means of producing biotypes. Recently, laboratory methods for inducing sexual morphs and hatching the eggs produced has allowed us to study the genetic variation and inheritance in greenbugs through biotype crossbreeding experiments.

All possible crossing and sib-mating combinations between biotypes C, E and F were made. The resulting F₁ progeny were evaluated against greenbug susceptible 'Triumph 64', and cultivars with greenbug resistance from 'Amigo' and 'Largo'. Greenbug virulence to both 'Amigo' and 'Largo' is determined by 3 genes that follow the Mendelian model of inheritance. The genes regulating virulence to a particular plant resistance gene are the same between biotypes. Virulence was recessive while avirulence was dominant. Therefore, avirulent biotypes that are heterozygous can produce virulent progeny when sib-mated during the sexual phase. New biotypes with host plant relationships unlike any previously described biotypes were produced in the laboratory.

MOLECULAR INTERACTIONS OF INTRACELLULAR SYMBIONTS AND APHIDS. H. Ishikawa, Zoological Institute, Faculty of Science, The University of Tokyo, Hongo, Tokyo 113, Japan.

It was suggested that the primary endosymbiont of the pea aphid *A. pisum* possesses a genome a few times larger than that of *E. coli*. The endosymbiont's genomic DNA is characteristic in that its G+C content is as low as 30 %. While endosymbionts of the pea aphid synthesize several hundred proteins when incubated in vitro, they do not synthesize any but an only one protein, symbionin, when present inside the host cell. One possibility is that symbionin is encoded by the host genome and is synthesized by the endosymbiont's ribosomes. Symbionin is an acidic protein with a molecular weight of 63000, and is produced primarily by the endosymbionts harbored by the embryo inside the mother's ovariole. Symbionin may be a storage protein which is consumed over the course of post-embryonic development of the host insect.

Since most of the aphid endosymbiont's genes are not expressed inside the host cell, like pseudogenes, they can be neutral to Darwinian selection and thus be fully susceptible to mutation. It was actually shown that the aphid endosymbiont's genome is undergoing evolution much more rapid than that of the host genome.

NUTRITIONAL INTERACTIONS BETWEEN MYZUS PERSICAE AND ITS SYMBIONTS. A.E. Douglas, Department of Zoology, Oxford University, Oxford, UK, OX1 3PS.

Aphids are believed to derive various amino acids from their intracellular bacterial symbionts. Radio-sulphur is incorporated from ³⁵S-sulphate into the essential amino acid methionine by *M. persicae* and its isolated symbionts but not by aphids freed from their symbionts by antibiotic treatment. At least 20% of ³⁵S is translocated to aphid tissues and it is proposed that methionine is the principal ³⁵S-release product of the symbionts. The contribution of symbiont amino acid synthesis to aphid nutrition is discussed.

GENETIC CHARACTERIZATION AND EVOLUTION OF THE PEA APHID SYMBIONTS. B.M. Unterman*, P. Baumann and D.L. McLean, Department of Bacteriology, University of California, Davis, California 95616.

The genes encoding for the 16S ribosomal RNA (rRNA) from the primary (P) and secondary (S) symbionts of the pea aphid (*Acyrtosiphon pisum*) have been cloned into *Escherichia coli*. The sequence of over 90% of the 16S rRNA has been determined. Analysis based on 603 nucleotide positions indicates that the P- and S-symbionts have a sequence similarity of 82%. The percent similarities between the P- and S-symbionts and the following species are indicated in parentheses following the species designation: *Escherichia coli* (84%,93%), *Proteus vulgaris* (83%,90%), *Pseudomonas testosteroni* (67%,70%), *Rochalimaea quintana* (a rickettsia) (63%,65%), *Bacillus subtilis* (60%,63%), *Mycoplasma capricolum* (55%,58%). These results as well as the presence of unique signature sequences indicate that the P- and S-symbionts are members of the gamma subdivision of the major evolutionary lineage defined by the purple bacteria. DNA restriction and Southern blot analysis suggests that both symbionts have only one rRNA operon in their genome. The presence of a single rRNA operon is unusual and may be characteristic of slow growing bacteria.

OVERVIEW AND CHALLENGES FOR THE FUTURE. R.K. Campbell, Department of Entomology, Oklahoma State University, Stillwater, Oklahoma 74078.

Aphids represent a vast and diverse assemblage of insects including many of economic importance by virtue of their detrimental effects to important crops. A complete array exists in which some aphids merely extract nutrients from their hosts while others effect severe toxic derangements and senescent like symptoms in theirs. In every case other factors, such as environmental influences, and saprophytic or symbiotic microorganisms, may play an influential role in modifying the ultimate outcome of aphid-plant interactions. Substantive progress will be made in the future elucidation of these processes only if understanding is obtained of the mechanisms by which gene products of all the organisms involved interact under varying environmental conditions.

IMPROVING HOST SUITABILITY THROUGH GENETIC SELECTION OF A PARASITE: THE CASE OF *COTESIA MELANOSCELA* AND THE GYPSY MOTH. R. M. Weseloh, Department of Entomology, Connecticut Agricultural Experiment Station, New Haven, Connecticut 06504.

Second generation *Cotesia melanoscela* do not complete development until after most gypsy moth larvae have reached instar IV, which they have difficulty parasitizing. To see if parasite females can be selected to develop faster, only the earliest emerging parasites in each generation were used to maintain the strain. Over six generations there was a non significant trend toward decreased development times. In another study parasites were only allowed to parasitize large larvae. Over 24 generations the selected strain eventually attacked larger hosts more successfully than did a non-selected strain. The usefulness of such selection as compared to other forms of manipulation are discussed.

HETEROISIS AND THELYTOKY IN THE GENUS *MUSCIDIFURAX*: PROBLEMS AND PROGRESS IN GENETIC IMPROVEMENT. E. F. Legner, Department of Entomology, University of California, Riverside, CA 92521.

Heterotic behavior in the genus *Muscidifurax* is expressed as increased longevity, parasitization rates, total fecundity, total progeny and host destruction. Hybrid dysgenesis may produce reduced values of these categories. Heterotic behavior resulting when newly introduced parasitoid strains interbreed with resident populations might facilitate field establishment of selected desirable traits. Thelytokous populations occur typically in geographically isolated areas. Incorporation of thelytoky in populations of genetically improved strains may slow loss of desired traits through reduced outbreeding. Heritable differences in behavior may be demonstrated immediately after mating at an intensity dictated by the male's genome. The induced traits are subsequently expressed by virgin offspring. Variable degrees of expression in backcrosses are consistent with a polygenic mode of inheritance. Postulated mechanisms for this "accretive" inheritance involve free DNA, chemical substances and/or microorganisms in the seminal fluid. Determinations of proportional activity increases in hybrids varies with the calculation method; population based values probably giving more reliable estimates of field performance.

GENETIC IMPROVEMENT OF A PARASITOID BIOLOGICAL CONTROL AGENT: ARTIFICIAL SELECTION FOR INSECTICIDE RESISTANCE IN *APHYTIS MELINUS* (HYMENOPTERA: APHELINIDAE). Jay A. Rosenheim* & Marjorie A. Hoy, Department of Entomology, University of California, Berkeley, California 94720 U.S.A.

Populations of *Aphytis melinus* DeBach, a parasitoid of California red scale, *Aonidiella aurantii* (Maskell), in citrus, were artificially selected for increased tolerance to five insecticides commonly used in citrus IPM. Selection produced gradual, small to moderate increases in resistance, accompanied in three of 12 selected lines with apparent decreases in genetic variation for pesticide tolerance. LC50 values for carbaryl increased to 5-fold that of the original field population and ca. 20-fold that of a susceptible natural population. Major resistance phenotypes were not detected in large field samples of *A. melinus*, suggesting that such phenotypes are either present at low frequencies (less than 5.2×10^4 for dimethoate resistance) or are entirely absent from the sampled populations. Bioassays of carbaryl residues revealed more than 50% survival of the carbaryl-selected strain as early as 18 days post-treatment, while the base colony continued to suffer more than 86% mortality on 75-day-old residues, the oldest tested. Because larval *A. melinus* are protected from insecticides within their scale insect hosts, this observed increase in carbaryl tolerance may enable *A. melinus* to persist in carbaryl-treated groves.

SELECTION FOR PESTICIDE RESISTANCE IN TWO *APHYTIS* SPECIES. Abraham Havron* and David Rosen, The Hebrew University, Faculty of Agriculture, Rehovot, Israel.

Two species of *Aphytis* Howard (Hymenoptera: Aphelinidae), effective parasites of armored scale insects (Homoptera: Diaspididae), were chosen to test the feasibility of breeding parasitic wasps for pesticide resistance: *A. holoxanthus* DeBach, a highly successful natural enemy of the Florida red scale, *Chrysomphalus aonidum* (L.), and *A. coheni* DeBach, an important natural enemy of the California red scale, *Aonidiella aurantii* (Maskell).

Out of 10 populations of *A. holoxanthus*, collected in different regions of Israel and tested for their tolerance to azinphosmethyl, carbaryl and permethrin, one was found to be 3.8 times more tolerant to azinphosmethyl than a susceptible laboratory population. This tolerance was also the most variable. Selection of this population for 15 generations has resulted in a further 4-8-fold increase in azinphosmethyl resistance.

A population of *A. coheni*, discovered in a heavily treated citron orchard, was found to be 10-12 times as tolerant to azinphosmethyl and twice as tolerant to permethrin as the susceptible population. This strain is currently being selected for resistance to each of these pesticides.

SELECTING *TRIOXYS PALLIDUS* FOR WALNUT IPM. F.E. Cave* and M.A. Hoy, Department of Entomological Sciences, University of California, Berkeley 94720, U.S.A.

Populations of the walnut aphid parasitoid, *T. pallidus* (Haliday) (Hymenoptera: Aphididae), surveyed for azinphosmethyl resistance, showed variability in concentration/mortality lines. All colonies subsequently selected with azinphosmethyl gave a gradual selection response. An interim analysis of selection response showed that a pooled selected (R) colony had a 4.5- and 7.0-fold greater LC50 than the pooled base and susceptible (S) colonies, respectively. The R strain showed greater survival than the S strain on fresh and aged azinphosmethyl residues on potted walnut trees and field-collected foliage after commercial application of a field rate. The R strain also produced 6.7-fold more progeny than the S strain when allowed to parasitize aphids on azinphosmethyl-treated potted trees.

SELECTING *TRICHOGRAMMA* SPP. AND *ANASTATUS JAPONICUS* ASHMEAD FOR RESISTANCE TO PESTICIDES.

Li Li-ying*, Xu Xiong & Zhang Min-lin, Guangdong Entomological Institute, Guangzhou, China.

5 years (1983-1987) tests on selecting *Trichogramma japonicum* and *T. confusum* for resistance to some pesticides showed the difficulties in selection. Other methods of treatment should be considered.

For selecting resistant strain of *Anastatus japonicus* to dipterex, the tolerance of this parasite to dipterex was examined. It showed, that the egg, larval, prepupal and pupal stages in host are 30-80 times more tolerant than the adult. In vitro rearing method of treatment was used too.

EVALUATION OF FIELD- AND LABORATORY-SELECTED PYRETHROID-RESISTANT PREDATORY MITES. N.P. Markwick, Entomology Division, Department of Scientific and Industrial Research, Mt Albert, Auckland, New Zealand.

Laboratory-selection and field-selection in New Zealand has produced two strains of the predatory mite *Typhlodromus pyri* Scheuten, which are resistant to synthetic pyrethroid (SP) insecticides at rates used commercially against leafrollers. *T. pyri* is used in integrated pest management programmes to control European red mite (ERM - *Panonychus ulmi* Koch) in pipfruit orchards. Selections were carried out with cypermethrin, but there is good cross-resistance to deltamethrin and fenvalerate and most of the "third generation" SP's tested. *T. pyri* in New Zealand was already resistant to organophosphate insecticides and this resistance has been shown to be retained in the two SP-R strains. Both resistant strains have successfully established, increased, overwintered and controlled ERM under an SP-spray programme in research orchards and on four commercial properties. Laboratory and field studies are now underway to determine the stability and rate of spread of the SP-resistance. As well, discussions on the commercial introduction of SP-R predators into pipfruit orchards are concentrating on bulking up supplies, distribution, grower education and co-operation with the chemical industry.

SELECTION FOR PYRETHROID RESISTANCE IN *AMBYSEIUS FALLACIS* IN MICHIGAN: REVIEW AND CURRENT STATUS. K. Strickler*, M. E. Whalon, Dept. of Entomology, Michigan State University, East Lansing, MI 48824, U.S.A.; B. A. Croft, Dept. of Entomology, Oregon State University, Corvallis, OR 97331, U.S.A.; and N. Cushing, 721 A. N. Appleton St., Appleton, WI 54911, U.S.A.

A greenhouse selection begun in 1979 yielded a pyrethroid resistant strain of the predatory phytoseiid mite, *A. fallacis* after 18 months and 16-21 selections. The selected strain showed multiple resistances to DDT and azinphosmethyl, and cross resistances to other S-P insecticides. Resistance appeared to be polygenic, and to be due to hydrolytic esterase and kdr mechanisms. When released into apple trees, selected mites survived pyrethroid treatment whereas susceptible mites did not. Resistance has persisted as pyrethroid use has become more common. Implementation of resistant predators has been informal, but attempts are being made to determine the extent and impact of releases.

SELECTION OF *METASEIULUS OCCIDENTALIS* (ACARINA:PHYTOSEIIDAE) FOR RESISTANCE TO PERMETHRIN AND ABAMECTIN. Y.L. Ouyang* and M.A. Hoy, Department of Entomological Sciences, University of California, Berkeley 94720, U.S.A.

M. occidentalis was selected with permethrin and abamectin in the laboratory. A 13-fold increase in LC_{50} was observed after 18 selections with permethrin, and a 3.8-fold increase was obtained with abamectin after 20 selections. A mode of inheritance test with permethrin suggested resistance was polygenetically determined. Life tables for the permethrin-resistant, -susceptible, and a wild colony were compared; intrinsic rates of increase and mean generation times (days) for these colonies were 0.165, 13.09; 0.174, 15.28; and 0.154, 10.22, respectively. The permethrin-resistant strain is more resistant than a previously selected strain, and is currently undergoing field evaluation. The abamectin-selected strain is unusual in that resistant females can deposit more eggs than susceptible females. *M. occidentalis* now has acquired resistances to organophosphate, carbamate, pyrethroid, sulfur, and abamectin pesticides through laboratory or field selections. This diversity of resistances rivals that of many pest arthropods.

GENETIC SELECTION AND EVALUATION OF NONDIA-PAUSING *APHIDOLETES APHIDIMYZA* (DIPTERA:CECIDOMYIIDAE) FOR CONTROL OF GREENHOUSE APHIDS IN WINTER. L.A. Gilkeson, Applied Bio-Nomics Ltd., P.O. Box 2637, Sidney, British Columbia, Canada V8L 4C1.

A. aphidimyza is a promising biocontrol for aphids, but its effectiveness in greenhouses is restricted by diapause in the fall. Five nondiapausing lines of *A. aphidimyza* were selected under LD 8:16 (21°C). One line was maintained for 50 generations (3 yrs.); selection did not affect fecundity, sex ratio, or morphology. When selection was relaxed, no significant reversion to higher diapause incidence occurred until after 8 generations. Larvae from selected lines still diapaused when reared under LD 8:16 and a thermoperiod of TC 21:15°C, however, low intensity radiation (below 48 $\mu W/cm^2$) at night prevented diapause under these conditions.

LABORATORY SELECTION OF THE COMMON GREEN LACEWING, *CHRYSOPELTA CARNEA* (STEPHENS), FOR PESTICIDE RESISTANCE. E. E. Grafton-Cardwell, Department of Entomology, University of California, Davis, California, 95616, USA.

The insect predator, *C. carnea*, was chosen for selection because it is an efficient generalist predator and is easily mass-reared or manipulated using food sprays. Laboratory selections for resistance to the commonly used pesticides carbaryl and diazinon were attempted with *C. carnea* larvae. These pesticides are needed in agriculture to control pests which have no effective natural enemies. Selection for field rate levels of resistance to carbaryl in *C. carnea* was successful after only 4 generations. In contrast, no response to 3 rounds of diazinon selection occurred in *C. carnea*. The selected carbaryl resistance was not inherited as a single dominant gene. Thus, carbaryl must be used periodically to maintain the resistance levels of the selected strain. Alternatively, the selected strain could be released in the absence of a native population of lacewings, such as the greenhouse. The carbaryl-resistant strain exhibited lower larval and pupal survival and produced fewer females than the colony from which it was derived, however, fecundity and adult longevity were increased.

ANALYSIS OF METHIDATHION RESISTANCE IN *PHYTOSEIULUS PERSIMILIS*. M. Pralavorio, D. Fournier & J.B. Berge, Centre de Recherches d'Antibes, Station de Recherches de Nématologie et de Génétique Moléculaire des Invertébrés, 06606 Antibes Cédex, France.

Seven strains of *Phytoseiulus persimilis* were selected for their resistance to methidathion. These strains were mixed and selected again. Usually the levels of resistance obtained allows the use of methidathion simultaneously with biological control of *Tetranychus urticae* by *P. persimilis*. In this case the product killed only a part of the resistant population when the sensitive one was fully eliminated. Determination of fitness and resistance stability is essential for an efficient use of beneficial arthropods in biological control. Therefore some fitness parameters were measured in selected populations. The results show that the demographic parameters are unaltered in the resistant strain. When resistant and sensitive strains were mixed, absence of insecticide pressure did not induce any loss of resistance. Resistant strain metabolized methidathion faster than the corresponding susceptible counterpart. The main part of metabolism was characterized as a glutathione dependant one. In resistant strain glutathione transferase has a three-fold lower apparent K_m which indicates that this enzyme is involved in the resistance of that *P. persimilis* strain. Backcrosses analysis has shown that there is only one character involved in resistance. Genetic analysis (backcrosses, selection of lines..) indicate that this resistance is a polyfactorial kind, and that it is impossible to select resistant strains in order to obtain sensitive ones. Nine lines submitted to selection over 10 acquired resistance. All these results indicate that there is a very high mutation rate which may be due to a genic amplification rather than to a point mutation.

THE POTENTIAL FOR RECOMBINANT DNA TECHNOLOGY IN GENETIC MANIPULATION OF ARTHROPOD NATURAL ENEMIES. Marjorie A. Hoy, Department of Entomology, University of California, Berkeley, CA 94720.

Genetic manipulation through recombinant DNA techniques (rDNA) offers the possibility that genes isolated from different species can be introduced into arthropod natural enemies. If desirable genes can be identified, cloned, inserted into the genome, transmitted stably, expressed appropriately, and transmitted to progeny, then we will have a useful new technique for developing improved natural enemies as well as developing fundamental understanding of gene structure, function, and regulation in beneficial arthropods. Efficacy and safety information will be required before releases can be made; release and evaluation protocols will have to be developed if improved strains are to be approved for release.

REGULATORY ISSUES IN RELEASING GENETICALLY-MANIPULATED ARTHROPODS. Max J. Whitten, Chief, Division of Entomology, CSIRO, Canberra, Australia.

Efficacy and specificity are often regarded as the two major criteria to be satisfied before release of natural enemies can be approved by regulatory authorities for biological control purposes. In no significant instance has a release following comprehensive safety testing led to serious unintended adverse effects on non-target organisms. One probable cost of this generally conservative approach may have been the failure to release natural enemies whose impact would have resulted in a net benefit. Furthermore, in no case where the natural enemy has been selected to improve its efficacy, has the artificial selection appeared to compromise specificity and safety. The recent public interest, over the proposed release of natural enemies that have been genetically manipulated by recombinant-DNA technologies, has caused monitoring and regulatory authorities in some countries, especially the USA, to emphasise the product rather than the process. This line of thinking has been applied by NIH to pathogens including viruses and bacteria, e.g. nuclear polyhedrosis viruses, *Pseudomonas syringae* and *P. fluorescens*. One consequence of this shift in attitude has been a diminution of the mystique and concern over the release of organisms manipulated by recombinant-DNA techniques. However, a more pertinent consequence for practitioners of classical biological control, regardless of whether the natural enemy intended for release has been manipulated by classical genetic procedures or has been subjected to no deliberate selection, could be the greatly increased demands by regulatory authorities for more substantial evidence that the proposed release will have no adverse environmental impact. It should also be noted that the inability to predict success is sometimes regarded as evidence that authoritative claims against adverse impacts should be qualified. It is difficult to suggest general remedies for these dilemmas because of the diverse political, social and legal nature of the countries engaged in biological control activities. The relevance of *Biological Control Act 1984* in the Commonwealth of Australia to rational community debate and decisions by regulatory agencies in Australia will be discussed. However, the solution proposed may be less suited as a model for countries whose legal and legislative systems do not stem from the British tradition.

CONSERVATION OF NATURAL ENEMIES: PRECEPT, PAYOFF, AND POLICY IN IPM FOR TROPICAL RICE. P.E. Kenmore, FAO P.O. Box 1864, Manila, Philippines.

Integrated Pest Management (IPM) for tropical rice depends on conservation of a large community of indigenous predators and parasites to keep hemipteran and lepidopteran pests controlled. If farmers destroy these communities, outbreaks of potential pests are often devastating. IPM extension begins by training extension workers and farmers how to differentiate predators from pests and insect damage from disease symptoms, so they decide to use insecticide only when insect populations are dangerous and not under control. Teaching these skills to tens of millions of rice farmers is a great challenge to extension systems but FAO-developed methods to teach them and measure how well they are taught are routinely used in Philippines, Malaysia, Sri Lanka, and Indonesia. Subsequent reductions of farmers' costs, increases in profits, and reductions in risk have proven IPM to be the most profitable and most assured crop protection strategy for hundreds of thousands of small farmers. National governments, after calculating benefits to national agriculture in the tens of millions of dollars, declared IPM in rice to be national policy, which creates uniquely supportive environments for further extension.

BIOLOGICAL CONTROL IN PEST MANAGEMENT ON OIL PALMS IN PAPUA NEW GUINEA. R.N.B. PRIOR, PAPUA NEW GUINEA OIL PALM RESEARCH ASSOCIATION.

The oil palm *Elaeis guineensis* is an introduced plant to Papua New Guinea and between 1968 to date some 40,000 hectares of plantation and smallholding have been established. Many of the major insect pests of oil palm in other regions are present in P.N.G.

Two defoliators, long horned grasshoppers of the tribe *Sexavae* (Orthoptera: Tettigoniidae) and bagworms (Lepidoptera: Psychidae) occur regularly and in outbreaks are controlled chemically by trunk injection. No spraying of insecticides except in the nursery or in trials has ever been carried out on oil palm in P.N.G.

In practice trunk injection has avoided insecticidal effects on adult parasitic Diptera (7 species recorded from Psychidae) and Hymenoptera (3 species from Psychidae), the Strepsipteran and Dipterous internal parasites of the *Sexavae* and the six species of *Sexavae* egg parasites (Hymenoptera). During the past eighteen months two of the *Sexavae* egg parasites, *Leefmansia bicolor* Waterst. (Hymenoptera: Encyrtidae) and *Doirania leefmansii* Waterst. (Hym: Trichogrammatidae) have been mass reared by new techniques described.

The recent introduction to PNG, where natural pollinators of oil palm are absent, of a pollinating weevil from Africa, encourages the restriction on insecticidal spraying. Judicious use of herbicides is also considered an important aspect of pest management to maintain necessary weed host plants for parasitic Hymenoptera and Diptera within the plantations. Pest management costs including chemical, biological control and monitoring are currently less than 1 dollar (US) per hectare.

BIOLOGICAL CONTROL OF INSECT PESTS IN ANNUAL CROPS IN MALAYSIA. G.S. Lim* and T.H. Chua; MARDI, Serdang, Selangor, Malaysia, and University of Malaya, Kuala Lumpur, Malaysia.

Annual crops in Malaysia are mostly grown in smallholdings by poorer farmers. Except for rice, sugarcane and certain vegetables which are more extensively grown, and wherein some biological control is practised or investigated, pest control in annual crops is mainly by chemicals. Although biological control is incorporated, their tactical approach differs. Rice pests in general are controlled naturally through natural enemy conservation. In brassica vegetables, it is mainly through parasitoid introductions against diamondback moth. However, for sugarcane stem borer inundative release is adopted.

During program implementation, many biological and social constraints are encountered. These are appraised, along with other discussions on their historical development, impact evaluation and potentials, management strategies and future considerations.

BIOLOGICAL CONTROL IN FOREST PEST MANAGEMENT.

D.L. Dahlsten* and H.F. Evans, Div. Biol. Control, Univ. California, Berkeley, CA 92740, USA and Forestry Commission, Alice Holt, Farnham, Surrey, GU10 4LH, England

Forests, by virtue of their special characteristics of size, complexity, longevity and relatively low economic thresholds, present special problems in evaluating the dynamics of pest insects and, more particularly, their natural enemy complexes. In this paper we attempt to place these problems in perspective, concentrating on the essential requirements of sound sampling regimes as bases for evaluating the roles of natural enemies in the observed dynamics of their host insects. Using such data we examine the ways in which biological control can be brought into forest management practice; the relative merits of natural enemy importation, augmentation or conservation are considered from both the theoretical and the practical points of view. Examples will be presented to illustrate these principles and also to examine the relative prospects for biological control in the intensively managed semi-natural forests of Europe and the more ecologically stable forests of North America.

ROLE OF BIOLOGICAL CONTROL IN IPM PROGRAMS IN ISRAEL.

David Rosen, Department of Entomology, The Hebrew University, Faculty of Agriculture, Rehovot 76100, Israel.

Integrated pest management (IPM) is the art of the possible, harmonizing all available methods to attain optimal pest control and environmental quality. This can be effectively achieved by judicious use of relatively selective pesticides, only when absolutely necessary and in the least disruptive modes of application, in combination with a vigorous program of biological control. Other selective techniques may be incorporated in an IPM program whenever applicable, but biological control by natural enemies should always be a major component.

In Israel, biological control has been widely accepted as the mainstay of IPM programs. Importation of natural enemies and/or their conservation have been the keys to IPM on major crops such as citrus, avocado or cotton. High levels of education and organization, and excellent extension services, have been instrumental in the development of integrated pest management in Israel.

INTERNATIONAL ASPECTS OF BIOCONTROL AND IPM. D.J. GREATHEAD, CAB International Institute of Biological Control (CIBC), Imperial College, Silwood Park, Ascot, Berks. SL5 7PY, UK.

Biocontrol agents for "classical" biocontrol and sometimes agents for use in augmentative biocontrol or for development as biopesticides are usually obtained from a region remote from where they are to be applied. Since most crops are attacked by a complex of pests biocontrol usually has to be a component of IPM. International collaboration is essential to the procurement of exotic agents and is beneficial in developing IPM, although it can only assist in establishing principles and strategies because detailed procedures must conform with local requirements. Previous conferences have identified the need for an information network and arrangements for reciprocal use of facilities by exploratory scientists. Suggestions will be made, for subsequent discussion, on how these needs may be met.

WHITEFLIES: DIVERSITY, BIOSYSTEMATICS AND EVOLUTIONARY PATTERNS. R.M. Bink-Moenen* and L.A. Mound, Department of Entomology, British Museum (Natural History), Cromwell Road, London SW7 5BD, UK.

Whiteflies are mainly tropical in distribution. As a result, knowledge of their taxonomy and biology is much more imperfect than that of aphids. About 1,200 species have been described, mainly from pupal cases. Adults of only a few species are known, and no comparative study of these has been made. Pupal cases provide useful biological data in that they are attached to their hosts, but they vary in structure depending on the host leaf surface thus making identification difficult. The classification of whitefly at genus and subfamily levels is inadequate. Examples are given of the value of studying adults, both at species and genus level, and suggestions are made for future research.

HOST-PLANT SELECTION AND HOST-PLANT PREFERENCE IN WHITEFLY: ITS CONSEQUENCES FOR POPULATION DYNAMICS. J.C. van Lenteren and L.P.J.J. Noldus, Department of Entomology, Agricultural University, Wageningen, the Netherlands.

Several species of whitefly are key pests nowadays, e.g. *Bemisia tabaci* in cotton and *Trialeurodes vaporariorum* in greenhouse crops. Chemical control of these pests is, or will soon be, very difficult due to pesticide resistance. For development of other pest management strategies like culture methods, host-plant resistance and biological control, detailed knowledge of whitefly biology on different crops is essential. For *T. vaporariorum* this is available, for *B. tabaci* and some other whitefly pest species it is not. In the paper we will address the following questions: 1. How do whiteflies locate their oviposition and feeding substrate? (selection before - after landing. 2. Is there a relationship between host-plant preference and host-plant quality? (developmental rates, mortality, quality of emerging offspring). 3. Are host-plant preference and quality fixed phenomena? 4. Can we explain whitefly population dynamics based on selection behaviour and plant quality characteristics? 5. Can we estimate the chances for biological control of whitefly pests with our present knowledge; if not what kind of information is lacking?

BREEDING FOR RESISTANCE AND OTHER PLANT CHARACTERISTICS RELATED TO WHITEFLY (HOMOPTERA: ALEYRODIDAE) CONTROL. O.M.B. de Ponti, Research Institute for Plant Protection (IPO), Wageningen, The Netherlands and L.R. Romanow, Raleigh, North Carolina (USA).

Although differences in host plant suitability for the most damaging whiteflies *Trialeurodes vaporariorum* and *Bemisia tabaci* were demonstrated between crop species and also between crop cultivars deliberate breeding for resistance has been limited to tomato and cotton.

In tomato this has resulted in advanced lines on which the number of whiteflies in the second generation after inoculation was reduced by up to 80% as compared to a susceptible control. This resistance originates from the wild related species *Lycopersicon hirsutum glabratum*; the mechanism of this resistance is unknown. Fruits of these lines have not shown increased levels of tomatine or other glycoalkaloids. 2-tridecanone, present in type VI trichomes of another accession of *L. hirsutum glabratum* caused high mortality of glasshouse whitefly adults.

In cotton selection and breeding for resistance under field conditions in the Sudan has resulted in the identification of breeding material with increased levels of resistance partly due to morphological characteristics.

In addition to host plant resistance plant breeding can also contribute to control of whiteflies by changing the morphology of plant to promote the effectiveness of parasites.

SAMPLING AND DISTRIBUTION OF WHITEFLIES. B.S. Ekblom* and Xu Rumei, Department of Plant and Forest Protection, Swedish University of Agricultural Sciences, Box 7044, S-750 05 Uppsala, Sweden and Department of Biology, Beijing Normal University, Beijing, China.

One of the most important factors in any sampling plan is the determination of the spatial distribution of the target insect. Most studies on whiteflies have shown that both adult and immature stages have aggregated distributions. This aggregation is not only per plant or tree but also per leaf and within the leaf which complicates sampling. Between plant distribution may tend to show some foci from which the adult whiteflies spread. Within plants the immature stages of whiteflies, which are relatively immobile, show a definite vertical distribution. Eggs and young larvae occur on the uppermost and youngest leaves while older nymphs and pupae are found on older leaves. The biology and behaviour of the whitefly are important in determining the spatial distribution. Problems with determining sample unit and sample size for both research and control decision-making for different species of whiteflies will be discussed.

ALEYRODID POPULATION DYNAMICS AND MODELLING. J. Baumgärtner (Institute of Plant Sciences, ETH, Zurich, Switzerland) and E. Yano (National Institute of Agro-Environmental Sciences, Kannondai 3-1-1, Yatabe, Tsukuba, Ibaraki 305, Japan).

Dynamic simulation models for aleyrodid systems are reviewed with particular reference to objectives for modelling, to methods used, and to results obtained. A relational diagram for an idealized tritrophic systems model is presented to facilitate comparisons between (a) aleyrodid population models with temperature as the driving variable, (b) an aleyrodid-plant population model with temperature, solar radiation, stress factors for plant growth and parasitism as the driving variables, and (c) an aleyrodid-parasitoid population model with temperature and plant influences as driving variables. The studies show that aleyrodid populations tend to increase exponentially in many agro-ecosystems until they reach limits set by the host plant. In model (a) temperature and plant species are the important factors, while model (b) was very sensitive to stress induced changes in the growth pattern of the host plant as well as to temperature. Furthermore predicted infestation patterns depend on both immigration rates and within plant dispersal. As opposed to (a) and (b) natural enemy activity in (c) drives the aleyrodid system into cyclic oscillations. A better understanding of multispecies interactions in the form of herbivory, predation and competition is concluded to improve explicative and predictive capabilities of the models. Furthermore they may become more realistic and practical when including spatial dynamics and the effect of management practices.

NATURAL ENEMIES OF WHITEFLIES: A REVIEW. D. Gerling*, Department of Zoology, Tel Aviv University, Ramat Aviv 69978, Israel and J. Fransen, Research Station for Floriculture, Aalsmeer, The Netherlands.

Numerous fungi, especially *Aschersonia* spp. kill whitefly adults and nymphs in humid environments both on trees and on low-lying plants. Predators of whiteflies include mainly Coccinellids, Heteroptera, Phytoseiid mites, Drosophilids and Chrysopids. Most species are predaceous as larvae and adults, and prefer fresh eggs and young nymphs. Many, especially Heteroptera and acari feed also on other prey and on plant material. Parasitoids of whiteflies oviposit and develop internally, except *Eretmocerus* which lay under the host but penetrate as 1st instar larvae into the 4th instar nymphs. Parasitization occurs in various instars but whitefly development is arrested following the 4th instar, except in *Cales* where arrestment starts shortly after oviposition. The parasitoids have no diapause and overwinter as immatures or adults. All genera except *Amitus* are synovigenic. Whitefly honeydew attracts the parasitoids. Short distance finding is at random. Most *Encarsia*, some *Eretmocerus* and *Euderomphale* are oligophagous. Defensive adaptations of whiteflies include adult oviposition behavior, spines and wax filaments on the nymphs.

WHITEFLIES IN AGRICULTURAL SYSTEMS. T. S. Bellows, Jr.*, D. N. Byrne and M. P. Parrella, Department of Entomology, University of California, Riverside, California, USA 92521.

Whiteflies occur as pests in several agricultural settings. Whiteflies are of tropical origin, and most of the more than 1600 known species are associated with perennial host plants. Certain of these are pests of perennial crops such as citrus. Those few that are capable of reproduction on herbaceous hosts are the same species that are identified as agricultural pests of annual crops. Systems where these herbaceous feeders are problems include cotton, lettuce, certain solanaceous crops, some leguminous and cucurbitaceous crops. These hosts are found both in the field and grown in glasshouses.

Damage to crops by whiteflies occurs in three ways. The most important of these results from their abilities as vectors of viral pathogens. Damage may also occur from staining of the plant material by sooty mold which grows on honeydew produced by the nymphs. Finally, circumstantial evidence implies that excessive numbers can damage directly crop hosts and reduce production. The worldwide status of whiteflies as pests in crop systems is reviewed with reference to these three types of potential damage.

CHEMICAL CONTROL OF WHITEFLIES. V. Dittrich*, S. Uk and G. Ernst, CIBA-GEIGY Limited, Agricultural Division, Basle, Switzerland.

Whiteflies have reached the status of a major pest in both greenhouses and field cultures as a consequence of intensified crop production. A wide spectrum of insecticides used in frequent treatments to maintain high crop yield and quality exerted a strong selection pressure on whitefly populations. This resulted in resistance development and population acceleration.

Plant protection and whitefly control, in particular, are subjected to conditions of crop structure, plant density, micro meteorology, and pest bionomics. Spraying for whitefly control is severely limited by these parameters.

Successful tactics to control whiteflies have to be based on good resistance management. Resistance monitoring of local field populations is a basic requirement for this. Alternation of insecticides of different mode of action or use of such mixtures as means of preventing resistance to develop or overcoming existing resistance have to be explored experimentally using the target insects of the area where resistance occurs.

Behavior modification by irritation causing sustained flight or movement and consequent high energy consumption which impedes egg production and frustrates normal behavior such as partner finding, copulation, and oviposition, is suggested as one avenue to better and more efficient control of resistant whiteflies.

UTILIZATION OF NATURAL ENEMIES FOR WHITEFLY CONTROL. J.C. Orillon (France)

No Abstract

INTEGRATING BIOCONTROL OF WHITEFLIES INTO CROP MANAGEMENT SYSTEMS. Robert V. Dowell, California Department of Food and Agriculture, 1220 N Street, Sacramento, CA, USA 95814

Integrating biocontrol of whiteflies into crop management systems involves finding effective non-chemical controls for the whitefly that are compatible with the chemical sprays used against other pests of the crop. For perennial evergreens such as citrus, classical biocontrol is generally compatible with spray schedules designed to conserve the parasites of scale insects. These sprays are usually applied when the parasites are protected inside their hosts. In glasshouses, inundative releases of parasites can prevent whitefly numbers from exceeding economic injury levels. The parasites are effective when non-chemical controls are used for the other pests or when properly timed sprays of pesticides are used which are less toxic to the adult parasites. At lower glasshouse temperatures or on crops with hairy leaf surfaces, yellow sticky traps can be used with parasite releases to control whitefly numbers. On deciduous perennials such as grapes, removal of the overwintering whitefly hosts from around the crop will break the whitefly life cycle and prevent damage. Similar tactics are used on some annual field crops. Host plant resistance to whitefly feeding holds tremendous promise for whitefly control on annual field crops such as cotton.

EFFECTS OF GOVERNMENTAL REGULATION AND FINANCIAL SUPPORT. R.D. Goeden, Division of Biological Control, Department of Entomology, University of California, Riverside, California 92521, U.S.A.

Classical biological control of alien weeds, i.e., involving intentional introductions of natural enemies (mainly stenophagous, phytophagous insects to date), is one of the most heavily regulated of all subdisciplines in the field of biological control. Permission to import potentially useful insects for weed control now is sought in most countries undertaking biological control of a weed following precedent established early in this century in countries where this method has long been practiced, e.g., Australia. In North America, governmental control of traffic in imported insect agents is comprehensive, continually redefined, and demands documentation in ever greater detail. Therefore, classical biological control of weeds research with insects is highly regulated as a result of historical precedence, not because the well-studied, candidate biological control agents in question are intrinsically more harmful than alien arthropod pathogens or arthropodaphagous natural enemies. Unfortunately, imagined worse-case scenarios, not justifiable risk-taking, invariably guide bureaucratic assessments of the efficacy and potential safety of introduction of phytophagous insects as candidate agents. Assurances of absolute safety of introduction of weed-feeding insects are sought by regulatory officials from biological control scientists, who as biologists are accustomed to dealing with few absolutes in Nature.

The history of biological control of weeds teaches us that there is no substitute for dependable, long-term, ample funding of biological control of weeds projects. Governmental resources historically have provided the main means of funding and conduct of biological control of weeds research; although, commodity groups have become increasingly important as funding sources in some countries, e.g., Canada, in recent years.

DENSITY DEPENDENCE AND THE BIOLOGICAL CONTROL OF WEEDS.

J.H. Myers, The Ecology Group, Dept. Zoology and Plant Science, Univ. British Columbia, Vancouver, Canada.

Whether density dependent behavior is necessary for successful biological control of insects has become a heated controversy. Biological control of weeds provides an excellent arena in which to examine the controversial relationship between density dependence and biological control. Two different density dependent relationships can have major impacts on the success of biological control of weeds. If plant survival and reproduction are related to density, weed populations become very resilient to insect attack. Biological control agents reduce seed production of diffuse knapweed by 95%, but seedling survival improves and plant density does not change. Because intraspecific competition among plants prevents high levels of seed mortality from being translated into population reduction. Biological control by herbivorous insects has been successful for approximately 10-20% of the plant species for which control has been attempted. In these situations insects kill their host plants. Discrimination among host plants by ovipositing insects causes a contagious distribution of insects on plants. Although some insects may starve from over crowding on preferred individual plants, regional persistence of plants and insects is maintained.

POPULATION DYNAMICS OF WEED BIOCONTROL. M.J. Crawley, Silwood Park, Ascot, Berkshire, SL5 7PY, England.

The theoretical background to weed biocontrol is investigated in the light of current thinking on the determinants of plant population dynamics. From a comparison of successful and unsuccessful attempts at biological weed control, and from studies currently under way on the exclusion of herbivorous insects from natural plant communities using repeated application of chemical insecticides, general patterns of insect life history and plant demography are extracted. The question as to whether ecological theory can help in predicting the degree of success that might be achieved from a proposed biological control attempt is reviewed, and the usefulness of mathematical models of weed biocontrol is assessed.

A NEW BIOLOGICAL PHENOMENON: SOLITARY POPULATION WAVE, FOUND ON INTRODUCTION OF PHYTOPHAGES OF WEEDS. O.V. Kovalev, Zoological Institute, the USSR Academy of Sciences, Leningrad 199034, USSR.

In the process of acclimatization of *Zygogramma suturalis* F. (Coleoptera: Chrysomelidae) introduced to the USSR from Canada for biological control of *Ambrosia artemisiifolia* L. a new phenomenon has been found: a steady undamped wave of insects that moves without changing its shape and with a constant speed. This wave process, described in a form of a new mathematical model, is called a Solitary Population Wave (SPW). Solitary waves that move without changing their shape have been intensively studied in recent years in physical, chemical and biological media as solitons and autowaves. SPW are different from the similar processes and have been described by us for the populations with reference to the species introduced. The important effect of the SPW is a total destruction of the substratum, e.g. 100% destruction of weeds.

Later we found that SPW was formed at introduction of phytophages of weeds in America and Australia. No special study of them has been made.

SPRAY TECHNOLOGY AND IPM. F. R. Hall, LPCAT, OSU-OARDC, Wooster, OH 44691, USA.

Biotargeting as part of an IPM strategy can include a reduction in pesticide load by means of: improved distribution of toxicants by optimizing the match of delivery system with seasonal growth (foliar volume); alternate row and ULV techniques to optimize management strategies (predators) and weather opportunities; practical dial-in systems for adjusting sprays; and innovative systems (electrostatics) to selectively place pesticides within the target area. The biological effect depends on the toxicological properties of the AI, its formulation, the concentration and pattern of the dose at the point of action. Target coverage and ultimate response of insect and mite pests are frequently not well correlated. This suggests that there is a lack of basic understanding of the dose transfer processes. The delivery of a practical optimal dose transfer system for high value, high-risk crops, still lacks expertise on decision rules, on-farm records management, accurate weather predictions, and most importantly, basic information on placement rules. Adequate calibration and a lack of perception about economic gains by growers remains as obstacles to development of block-by-block strategies. Increased regulatory and socio-economic pressures may become added incentives for improved targeting in orchard ecosystems.

INSECT GROWTH REGULATORS (IGR), MIMICS OF JUVENILE HORMONE, AS MORPHOGENETICAL AND OVICIDAL MEANS OF CONTROL AGAINST ORCHARD TORTRICIDS. P.J. CHARMILLOT, Swiss Federal Research Station, Changins, CH-1260 Nyon, Switzerland.

Metamorphosis is regulated by a complex hormonal balance in which juvenile hormone (JH) plays an important part. At the last larval instar the content of JH is particularly low in the insect body. If an insect growth regulator (IGR) - a mimic of JH - is applied at this time, the pupal moult will be disturbed with the characteristic morphogenetical deformations. The JH content is also very low in fresh laid eggs. Therefore the IGR treatments can disturb the embryonic development of some species and produce an ovicidal activity. During a few years two IGR-fenoxycarb and CGA 45 128 were evaluated for their morphogenetical effect on the last larval instar of some species as *Adoxophyes orana* and *Pandemis heparana* and for their ovicidal effect on fresh laid eggs of *Cydia pomonella* and *Grapholita funebrana*. After a few years of experimentation and commercialisation in European orchards, IGR use confirmed that they present a considerable improvement in integrated pest management due to their selectivity, their low toxicity and their innocuity for useful fauna.

LIMITATIONS TO THE INTRODUCTION OF IPM INTO APPLE ORCHARDS IN THE NETHERLANDS. A.K. Minks^x, J. Woets and M. Trapman, Research Institute for Plant Protection, Wageningen, Fruit Growing Research Station, Wilhelminadorp and the Horticultural Advisory Service, Tiel, the Netherlands, respectively.

In 1986, the Netherlands Ministry of Agriculture decided to promote and introduce IPM into apple orchards through its horticultural advisory service, after more than 25 years of research.

The IPM-program in Dutch apple orchards consists of 2 major elements, namely (1) the use of the indigenous predatory mite species, *Typhlodromus pyri*, to control the fruit tree spider mite and the apple rust mite, and (2) the use of selective agents to control particularly caterpillars (mainly summerfruit tortricid, codling moth and winter moth).

Application of these biological and selective control methods favour the development of natural enemies and an increased suppressing action on in particular leaf-roller moths and aphids. Accurately established action thresholds are other means to further minimize the use of broad-spectrum insecticides.

The present state of the introduction of IPM will be discussed with special attention to selective control methods and some pests causing special problems.

MANAGING PREDATORS IN APPLE ORCHARDS IN THE UK.

M.G. Solomon, Entomology Section, Institute of Horticultural Research, East Malling, Maidstone, Kent, England ME19 6BJ.

IPM in UK apple orchards is centered on the regulation of the European red mite *Panonychus ulmi* by the phytoseiid mite *Typhlodromus pyri*. Organophosphate (OP)-resistant strains of the predator have become widespread in SE England, the major UK apple-growing region. Where a suitable pesticide programme is introduced, *T. pyri* has usually colonised the orchard during the first season, and has regulated *P. ulmi* at an acceptable level without the need for acaricide applications in most years. *T. pyri* also usually prevents the apple rust mite *Aculus schlechtendali* from building up to damaging numbers.

In some isolated areas where OP-resistant *T. pyri* has not colonised naturally, they have been artificially introduced from mass cultures or from other orchards.

Mite management based on OP-resistant *T. pyri* has been adopted by many growers, the main obstacle to its further spread being the use of synthetic pyrethroids. A low level of pyrethroid-resistance has developed in populations repeatedly exposed to low rates of pyrethroid in the field, and is being enhanced by further artificial selection.

APPLE IPM: SETTING THE THRESHOLDS FOR INDIRECT PESTS.

N.P.D. Angerilli, Agriculture Canada, Research Station, Summerland, British Columbia, Canada, V0H 1Z0

Setting economic damage thresholds for indirect pests of apple presents numerous technical, logistical and operational difficulties. Experiments utilizing European red mite (*Panonychus ulmi* (Koch)), apple rust mite (*Aculus schlechtendali* (Nalepa)) and the white apple leafhopper (*Typhlocyba pomaria* McAtee) suggest that yield, quality, return bloom and physiological effects vary with apple variety and certain horticultural practices. There are similarities and differences between the nature of the damage caused by mites and the leafhopper that must be accounted for in the setting of thresholds and the mitigation of the damage that they cause. The use of regression analysis and simple plant growth models may be of value in the development of thresholds for certain "groups" of indirect pests.

PHEROMONE TRAP DESIGNS. Charles Vincent, Station de recherches, Agriculture Canada, Saint-Jean-sur-Richelieu, Qué. CANADA J3B 6Z8.

Since the advent of commercially available pheromones, several pheromone trap designs have been tested throughout the world. In a research context, the use of different trap designs allow to test hypotheses on behavior, insecticide resistance, distribution and movements of lepidopteran pests. In an applied context, the promise of pheromone trapping was high at the beginning of the '70s, but very few examples of a significant relation was found between captures and damage at harvest. All other factors being equal, trap design is an important factor to explain capture levels. Actually, there seem to be non consensus on a standard pheromone trap model. The concept of trap performance will be discussed in light of results from the literature and from monitoring trials involving lepidopteran pests in apple orchards where sticky and non-sticky pheromone traps were used.

The need and the problems associated with the standardization of trap design will be addressed.

RESOURCE FORAGING BEHAVIOR OF APPLE PESTS IN RELATION TO PEST MANAGEMENT. R.J. Prokopy, Department of Entomology, University of Massachusetts, Amherst, Massachusetts, 01003, U.S.A.

The plum curculio, apple maggot, and codling moth are key pests attacking the fruit of apple trees in eastern North America. Using a variety of methodological approaches and in varying degrees of depth, we have investigated aspects of the fruit foraging behavior of each of these species. The knowledge gained has paved the way toward a more behavioral-ecological oriented approach to managing these pests in Massachusetts commercial orchards, which we term second-stage integrated pest management.

MASSACHUSETTS APPLE INTEGRATED PEST MANAGEMENT: MOVING TO A SECOND STAGE. W.M. Coli, Department of Entomology, University of Massachusetts, Amherst MA 01003, U.S.A.

Between 1978 and 1982, with funding provided by the United States Department of Agriculture, Massachusetts initiated a pilot IPM program in commercial apple orchards throughout the state.

Comparison of IPM blocks with check blocks indicated a reduction in pesticide dosage equivalents in IPM blocks of 30%, 54%, and 10% for insecticides, miticides and fungicides respectively, and an average savings of \$92.00 per acre (\$230/ha).

However, although insecticide use has continued to decrease in private-sector IPM blocks since 1982, miticide use has risen to pre-program levels, largely due to apparent mite resistance, and to the introduction of predator-harsh pesticides directed at other pests.

In 1987, we embarked on a new emphasis which we refer to as the "second-stage" of apple IPM. Initial work has focused on interception of immigrating apple maggot flies using odor and visual traps, removal of host trees within 200 m. of the orchard perimeter to preclude immigration of codling moth and summer leafrollers, and an investigation of orchard understory composition and management on biological control of orchard mites and overwintering apple scab inoculum.

MANAGEMENT OF PESTICIDE RESISTANCE AMONG ARTHROPOD PEST AND NATURAL ENEMIES OF APPLE. B.A. Croft, Department of Entomology, Oregon State University, Corvallis OR USA 97331-2907.

Evolution of resistance to pesticides in arthropod pests and natural enemies has been both a detriment and benefit to IPM systems for apple, globally. Among secondary pests, organophosphate (OP) resistance is widespread among spider mites, aphids, leafhoppers, and leafminers. Among tortricoid key pests OP resistance has become of increasing concern. Fortunately, for the ubiquitous codling moth, *Cydia pomonella*, OP resistance has not been documented. Among the natural enemies of many secondary pests, OP resistance has evolved both in the field and in the laboratory from artificial selection. Insecticide resistant natural enemies are widely employed on apple. Where synthetic pyrethroid (SP) insecticides have been widely used, resistance appeared rapidly in certain graciariid leafminers as predicted by IPM specialists. High-level, stable resistance to SP's have not been developed in any key natural enemies, either from artificial selection or in the field. Resistance to the physiologically selective organotin acaricides by spider mites is posing difficulties in maintaining IPM programs based on predaceous phytoseiid mites.

COMPUTER-AIDED DECISION MAKING FOR APPLE PEST MANAGEMENT. Sue Haley*, Kevin Currans and Brian Croft, Department of Entomology, Oregon State University, Corvallis, OR 97331, U.S.A.

Much apple pest management research during the past 15 years has been concerned with modeling interactions among the crop, its pests and their natural enemies. To have greater influence on pest management decision making on individual farms, research models must be integrated with site-specific data and with less quantitative knowledge based on the accumulated experience of researchers and practitioners. Recent developments in computer software have now made this task feasible.

We are developing a prototype computer system to help consultants, extension agents and growers make management decisions for codling moth, *Cydia pomonella*, San Jose scale, *Quadraspidiotus perniciosus*, and phytophagous mites in the western U.S.A. The system is designed so that other pests can be added and regional modifications made later. Our program identifies specimens of pests and pest damage, predicts crop damage from sample data and daily temperatures, and estimates control costs and benefits. A number of linked databases permit easy recording and handling of data from multiple sites. The program provides an individual and dynamic treatment threshold and allows the user to evaluate control alternatives on the basis of both short- and long-range effects.

FEASIBILITY OF TREE FRUIT IPM. G.A. Norton, Silwood Centre for Pest Management, Imperial College, Silwood Park, Ascot, SL5 7PY, U.K.

Despite 20 years of intensive research effort aimed at developing supervised control for insect pests in apple orchards, few growers appear to have adopted this practice. In the U.K., Fenimore and Norton (1985) identify four major reasons why this is the case -

- (i) growers employ routine, calendar spraying of fungicide against apple mildew, and can easily tank mix insecticide at little cost,
- (ii) it is difficult to design practical economic thresholds for a complex of pests and employ economic thresholds where weather is highly uncertain and management flexibility is limited,
- (iii) trained labour for identifying and monitoring pests is expensive or unavailable,
- (iv) the risk of lower quality fruit associated with failure of supervised control - for instance, where very heavy attack occurs - is unacceptable.

This paper re-examines the case for supervised control and the conditions under which it might become more feasible.

Fenimore, P.G. & Norton, G.A. (1985) Problems of implementing improvements in pest control: a case study of apples in the U.K. *Crop Protection* 4:(1), 51-70.

ORIENTAL FRUIT MOTH - IPM AND MATING DISRUPTION. R.E. Rice, Department of Entomology, University of California, Davis, California 95616.

Field trials using mating disruption as a control strategy for the oriental fruit moth, *Grapholita molesta* (Busck), have been carried out in several areas of North America since 1985. In California, a 3-component blend of OFM pheromone was placed into peach and nectarine orchards at dispenser densities of 1000 per ha. The pheromones were applied twice each season, at the first moth emergence in February, and again 3 months later. Efficacy of treatments was measured using standard pheromone traps, terpinyl acetate/sugar bait traps, mating success of trapped female moths, and infested fruit at harvest.

Results of these trials have shown complete disruption of male OFM response to pheromone traps, and marked reductions of both male and female collections in bait traps. In successful plots, mating success of females is both reduced, and delayed, in comparison to non-pheromone treated blocks, particularly in early generations. Inspections of infested fruit show the mating disruption technique to be competitive with standard insecticide spray programs. It is suggested that the basis for success of mating disruption is due to delayed mating of virgin females in each generation, with a concomitant reduction in viable eggs.

GENETIC IMPROVEMENT OF INSECTICIDE-RESISTANT PHYTOSEIID
MITES IN THE USSR. A.Z. Petroshova (USSR)

No Abstract

FUTURE PERSPECTIVES IN APPLE IPM. C. Vincent (Canada) and
B.A. Croft (USA)

No Abstract

ROBUSTNESS IN SAMPLING FOR PEST INCIDENCE. M.R. Binns*, Statistical Research, Engineering and Statistical Research Centre, Research Branch, Agriculture Canada, Ottawa, Ontario, Canada K1A 0C6.

There are many reports in the literature on sampling for levels of incidence of crop pests. Some are for fixed size sampling plans while others are for sequential plans, some involve total counts while others use binomial methods. All require assumptions on the form of distribution of the crop pest, and it is important to know how robust the methods are with respect to such assumptions. Several sampling procedures, some from the literature, are studied in this presentation for their robustness, and some recommendations are made.

THE USE OF ENTOMOPHAGOUS NEMATODES TO CONTROL BLACK VINE WEEVIL IN PACIFIC NORTHWEST CRANBERRY BOGS (COLEOPTERA: CURCULIONIDAE). G.C. Fisher*, C.H. Shanks, F. Agudelo-Silva, M.A. Morris, and A.P. Poole, Department of Entomology, Oregon State University, Corvallis OR 97331-2907.

The Black Vine Weevil (BVW), *Otiorhynchus sulcatus* (F.), is a serious pest of cranberry bogs in the Pacific Northwest. Damage results from root pruning and girdling by larvae. Because there are limited cultural and chemical means to control this pest, *H. heliothidis* was evaluated for its potential to biologically control this insect.

Satisfactory weevil control was obtained from soil applications of nematodes to infested commercial bogs. Larvae, pupae, and teneral adults were attacked by infective juveniles of this nematode species.

MONITORING BLACKHEADED FIREWORM (Lepidoptera: Tortricidae) IN CRANBERRY BOGS WITH PHEROMONE TRAPS. C.H. Shanks, Jr.*, Washington State University, Vancouver, Wash.; L.J. Dapsis, Ocean Spray Cranberries, Plymouth, Mass.; and L.M. McDonough, U.S. Department of Agriculture, Yakima, Wash., U.S.A.

The blackheaded fireworm (BF), *Rhopobota naevana* (Hubner), is a pest of cranberries in Canada and the United States. Two components of the female sex pheromone, (Z)-11-tetradecen-1-ol and (Z)-9-dodecen-1-ol acetate are, in combination, effective baits for traps for monitoring BF adult populations. The preferred proportion was 98:2. Traps in which baits were changed every 3 weeks were not more efficacious than those in which baits were unchanged for 16 weeks. Traps 30-60 meters apart often had very different catch numbers, showing that the moths are not evenly distributed and are weak fliers. Traps placed outside the bogs caught few moths, probably because of few wild hosts. The traps were useful in showing the time of moth emergence and variations in population levels.

INTERACTION OF CRANBERRY GIRDLER AND HOST PLANTS AS CRITERION FOR IPM (LEPIDOPTERA: PYRALIDAE). J. A. Kamm*, G. C. Fisher, L. M. McDonough, and C. H. Shanks. U. S. Department of Agriculture, Agricultural Research Service, 3450 S. W. Campus Way, Corvallis, Oregon 97331-7102.

The cranberry girdler, *Chrysoteuchia topiaria* (Zeller) is a univoltine pest of cranberries, grasses, and coniferous seedlings. The physical characteristics and production technology of each crop require different approaches to girdler management. The use of sex pheromone as a trap bait is an effective way to identify and assess girdler populations. Rubber septa loaded with 1000 µg (Z)-11-hexadecenal and 30 µg (Z)-9-hexadecenal are effective provided precautions are taken to prevent degradation in the septa. Seasonal flight of adults monitored with pheromone traps peaked remarkably close to 857° C heat units at four locations. At more northerly locations, peak emergence requires 15-20 percent fewer heat units. Factors that influence management practices of girdler populations are discussed for each crop in relation to crop habitat and production practices.

MONITORING OTIORHYNCHUS SULCATUS (FABRICIUS) AND O. OVATUS (LINNAEUS) (COLEOPTERA: CURCULIONIDAE) IN CRANBERRY BOGS. L. J. Dapsis, Ocean Spray Cranberries, Inc., 225 Water St. Plymouth, MA 02360 USA

Otiorhynchus sulcatus and *O. Ovatus* were new pests of Massachusetts cranberry bogs in 1986 although the insects were recorded in the state as introductions from Europe in 1831 and 1852 respectively. The cranberry, *Vaccinium macrocarpon* Ait., is native to North America and has been under cultivation since 1816. The technique of night sweep sampling was developed to monitor emergence of adult weevils and evaluate the impact of foliar insecticides. Surveys indicated that the two species did not occur together within the same bed of vines; water management practices were correlated with the presence of each species. Alternate host plants were identified and used as diagnostic aids to determine if symptoms of vine die-back in cranberry bogs was weevil related. In 1987, night sweep sampling was employed in Washington cranberries to monitor *O. sulcatus* adult activity and the impact of insecticides. Where applicable in Massachusetts and the Pacific Northwest flooding cranberry bogs after fall harvest is recommended to control weevil larvae.

IPM IN CRANBERRIES, AMERICA'S NATIVE FRUIT. J.A. Lasota, University of Massachusetts, Cranberry Experiment Station, East Wareham, Massachusetts, USA 02576

IPM in cranberries was initiated as a formal program in Massachusetts in 1983, and has markedly increased in popularity among growers in that state, the largest cranberry growing region in the world. Approximately eighteen insect and mite species comprise the arthropod pest complex, with varying degrees of damage intensity. Pest monitoring, through the use of sweep nets, pheromone traps, and vine and berry samples, has helped to significantly reduce insecticide usage. Together with the use of cultural control methods (i.e. the use of sand and water), the second phase of cranberry IPM includes the integration of microbials, entomophagous nematodes, and naturally occurring beneficials. The environmental and sociological implications of this program significantly influence grower support and public demand for alternatives to prophylactic, chemical controls.

MONITORING AND MANAGEMENT OF THE STRAWBERRY SAP BEETLE, *STELIDOTA GEMINATA* (SAY) AND THE STRAWBERRY BUD WEEVIL, *ANTHONOMUS SIGNATUS* SAY ATTACKING STRAWBERRIES. A.J. Howitt, Dept. Entomology, Michigan State University, East Lansing, MI 48823.

Small was cups filled with fermenting molasses were highly attractive and effective in trapping the strawberry sap beetle. When the cups were placed in the woods and around the strawberry plantings they monitored the activity and movement of adults from the woods into the strawberry plantings and provided the timing of spray applications. Bioassay of numerous pesticides determined that Diazinon and Azinphos-Methyl were the most effective pesticides. Diazinon 4EC or Azinphos-Methyl 25C at the rate of 1 pint and 2 pints, respectively, per acre introduced from a spray tank into the overhead irrigation system at the end of the sprinkling period gave effective control of this pest. The strawberry bud weevil migrated into strawberry plantings the year after planting and became a resident in the planting. There exists no good methods of monitoring other than searching for damage to the plant. Damaged buds and holes in the petals are easily discernable and indicative of strawberry bud weevil damage. Chlorpyrifos 4EC or Fenvalerate 2.4EC at 1 quart and 8 fl. oz. per acre, respectively, applied shortly after the buds push through the soil gave excellent control.

FIELD EXPERIMENTS ON ACARICIDAL CONTROL OF TWO-SPOTTED SPIDER MITES ON STRAWBERRIES IN SCOTLAND. R.G. McKinlay, Edinburgh School of Agriculture, West Mains Road, Edinburgh EH9 3JG, United Kingdom.

As a result of poor two-spotted spider mite (*Tetranychus urticae* Koch (Prostigmata:Tetranychidae)) control reported in several commercial strawberry crops in east Scotland after spraying with acaricides, field experimental work began in 1984 to compare the acaricidal effectiveness of sprays of organochlorine, organophosphate, organotin and pyrethroid pesticides. The pyrethroid pesticides in particular were shown to be useful alternative acaricides to the organochlorines. Strawberry yields were not however increased by the pyrethroid pesticides. Pyrethroids may have a direct physiological effect on strawberry plants which does not permit their acaricidal effectiveness to be expressed as increased yields.

CONTROL OF *TETRANYCHUS URTICAE* KOCH (ACARI, TETRANYCHIDAE) IN NEW ZEALAND BERRY FRUITCROPS. J.G. Charles*, W.P. Thomas, & P.J. Workman, Entomology Division, DSIR, Private Bag, Auckland, New Zealand.

Integrated control programmes for *Tetranychidae urticae* in strawberries, blackcurrants and raspberries are discussed. *T. urticae* is a major pest of most New Zealand berryfruit crops, which are grown primarily for export. Mite control is constrained by short growing seasons of the crops, a limited range of pesticides for which export residue tolerances are set, and the low levels of chemical residues that are acceptable on harvested fruit. The introduction of the predator, *Phytoseiulus persimilis* (Acari: Phytoseiidae), into New Zealand, and the registration of an effective strain of *Bacillus thuringiensis* for caterpillar control, has allowed the biological control of *T. urticae* to be integrated with the chemical control of insect pests. Augmentative releases of predatory mites may be necessary to control *T. urticae*. Timing the predator releases on the basis of historical data is often more effective than responding to *T. urticae* population monitoring, which may provide data that is difficult to interpret and, in any case, is too time consuming, and therefore expensive, for New Zealand berryfruit growers.

MANAGEMENT OF THE TWOSPOTTED SPIDER MITE, *TETRANYCHUS URTICAE* KOCH (ACARI: TETRANYCHIDAE) ON STRAWBERRIES. D.A. Raworth, Agriculture Canada Res. Sta., 6660 N.W. Marine Drive, Vancouver, B. C., Canada V6T 1X2.

A management program for *T. urticae* on strawberries was developed by linking a rapid sampling method (Raworth, D.A. and M. Merckens. 1987. J. Ent. Soc. Br. Columb. 84:17-18) with population growth-rate data and information on yield reductions at given densities of *T. urticae* (Raworth, D.A. 1986. Can. Ent. 118:9-16). The program was used commercially during 1987. The sampling part of the program produced accurate estimates of the density of *T. urticae* when mites were observed on more than 10% of the leaflets. Below that level the speed of sampling increased and mite densities were underestimated. This bias occurred at low mite densities and did not affect management decisions. Preliminary evaluation of the decision-making part of the program suggests that more than half of the 12 growers involved decreased their miticide usage by 50% from previous years.

Future work will focus on the development of a simulation model of *T. urticae* that will make the management program more dynamic, and the development of inundative biological control techniques that utilize *Phytoseiulus persimilis* Athias-Henriot, *Metaseiulus occidentalis* (Nesbitt) and *Amblyseius fallacis* (Garman).

POPULATION DYNAMICS AND CONTROL OF MITES ON STRAWBERRIES IN BULGARIA. N.D. Atanasov, Plant protection institute, 2230 Kostinbrod, P O B 238 Sofia, Bulgaria.

The appearance and the dynamics of *Tetranychus urticae* Koch., *Tetranychus turkestanii* Ugar. et Nik., and *Tarsonemus pallidus* Banks on strawberries grown in the field and under plastic has been established. The extremely high temperatures and the low relative humidity during July - August depressed the development and highly reduced the mites density. The number's variation in the populations of the mites on strawberries are due to a process of a complex relationships of plants, mites and natural enemies. It was determined that in the ratio 1:20 the predators can regulate the density of the tetranychid mites. The tolerance of some strawberry varieties to tetranychid mites is demonstrated. A system for integrated control was developed for the control of mites, grown in the field and under plastic.

PREDICTING EMERGENCE OF OVERWINTERED *RESSELIELLA THEOBALDI* (BARNES) (DIPTERA, CECIDOMYIIDAE) TO CONTROL 'MIDGE BLIGHT' IN RED RASPBERRY IN THE UK.

S.C. Gordon*, J.A.T. Woodford and I.A. Barrie².

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Raspberry cane midge (*R. theobaldi*) is an important pest of red raspberry (*Rubus idaeus*) in Europe. Midge larvae feed under the rind of primocanes in late spring and summer. Several species of fungi infect larval feeding sites and may kill canes before fruiting in the following year. This is known as 'Midge Blight' and has been controlled by decreasing midge populations, either directly with insecticides or indirectly by cultural methods. Cultural control has been achieved in vigorous cultivars by removing the first flush of primocanes in the spring. The replacement primocanes develop later and natural splits in the epidermis (the preferred oviposition sites) are no longer synchronised with midge emergence. The desiccant herbicide, dinoseb-in-oil was used to kill the primocanes but its recent withdrawal in the UK has forced attention on the accurate timing of insecticide application to coincide with midge emergence which varies with season. This paper outlines an emergence model for overwintered *R. theobaldi* based on meteorological data and its evaluation in the field.

MONITORING TARNISHED PLANT BUG, *LYGUS LINEOLARIS* (PALISOT DE BEAUVOIS) (HEMIPTERA: MIRIDAE) IN STRAWBERRY FIELDS. G. Mailloux (Station de recherche de St-Bruno, M.A.P.A.Q., St-Bruno, Quebec, Canada J3V 4P6) and N.J. Bostanian (Agric. Canada, Res. Station, St-Jean, Quebec, Canada J3B 6Z8).

The relationship between the density of *Lygus lineolaris* (P. de Beauvois), tarnished plant bug per strawberry blossom cluster and its impact on yield reduction was described by a non-linear regression equation. When only berry weight was considered, strawberries cv 'Redcoat' were found to have a carrying capacity of 0.90 nymphs per blossom cluster and an economic injury level of 0.95-0.99 nymphs per blossom cluster. However, when the percentages of uninjured berries were taken into account, then an action threshold of 0.26 nymphs per blossom cluster was established. Two sequential sampling plans based on the binomial distribution were developed for determining rapidly the need for control measures.

THE MANAGEMENT OF POLLINATORS AND INSECT PESTS IN STRAWBERRY PLANTATIONS. Charles Vincent^{*1}, Domingos De Oliveira², and André Bélanger¹, ¹Station de recherches, Agriculture Canada, Saint-Jean-sur-Richelieu, Qué. Canada J3B 6Z8, ²Département de Sciences Biologiques, Université du Québec à Montréal, Montréal, Qué. Canada H3C 3P8.

Modern strawberry cultivars may be pollinated by gravity, wind and insect visitors. Independent experiments conducted in Michigan, England and Quebec indicate that entomogamous pollination could contribute to up to 25 % of yield. The quality of the crop is also affected because poor pollination of flowers cause malformed fruit. Amongst the several insect species involved in pollination, the honey bee, *Apis mellifera* L. is a key player. In Eastern North America, insecticide treatments are applied at bloom against the tarnished plant bug, *Lygus lineolaris* (P. de B.) (Hemiptera:Miridae) and the strawberry weevil, *Anthonomus signatus* Say (Coleoptera:Curculionidae). This practice is also recommended in other parts of the world, notably Europe, where there are also mirid and curculio pests attacking the crop at bloom. We will discuss the value of insecticide treatment programs based on pest thresholds vs insecticide treatment programs that take into account the foraging activity of pollinators. The discussion will be based on data from the literature and data obtained from field experiments conducted for 3 seasons at Frelighsburg, Quebec.

SEASONAL DEVELOPMENT OF THE STRAWBERRY WEEVIL, *ANTHONOMUS SIGNATUS* (COLEOPTERA: CURCULIONIDAE) IN QUEBEC STRAWBERRY FIELDS. N.J. Bostanian (St-Jean Res. Station, Agric. Canada, St-Jean, Quebec, Canada J3B 6Z8) and G. Mailloux (Station de recherche de St-Bruno, M.A.P.A.Q., St-Bruno, Quebec, Canada J3V 4P6).

The phenology of *Anthonomus signatus* (Say) was studied in Quebec strawberry fields ('Redcoat') at L'Assomption and Frelighsburg from 1983 to 1987. The adults first appear in spring about the time the strawberry plant forms its first buds. Eggs are found from mid to end May. The larvae have three stages. The mean head capsule width (mm $\pm$ SE) for first, second and third instars are: 0.26 $\pm$ 0.002, 0.376 $\pm$ 0.013 and 0.510 $\pm$ 0.001. Morphometric data are given for each stadium. Sexes can be differentiated by external features. Pupation occurs at the beginning of July within the strawberry bud at the surface of the soil. Immature adults are noted at mid July and feed on strawberry leaves for a short period before going into estivation and hibernation in the same strawberry field.

A SMALL FRUIT IPM SCOUTING PROGRAM FOR NEW YORK STATE GROWERS. J. Kovach*, IPM Support Group, and G. A. Schaefer, Department of Entomology, Cornell University, NYSAES, Geneva, New York 14456.

The objectives of this program were to provide a scouting service to small fruit growers that would furnish timely information on pest populations to improve growers' knowledge of pest biology and the effectiveness of their pest management decisions. This project consisted of 26 growers, in nine counties, who paid \$25/ha with a \$50 minimum to have their small fruit acreage scouted. There were a total of 155 ha of blueberries and 16 ha of raspberries. Major pests scouted for included: the strawberry bud weevil, meadow spittlebug, tarnished plant bug, spider mite, root weevils, gray mold, red stele, and leather rot. Strawberry harvest evaluations and spray records were collected from 23 participating growers and from 10 non-participating growers to determine the effectiveness of the program. The research component of this program included investigations on ovarial development of *Otiorhynchus sulcatus* to improve treatment timing. Preliminary results indicate that treatment for root weevils should be applied in New York during the last week in July.

ENTOMOLOGICAL RESEARCH IN VIRGINIA (U.S.A.) VINEYARDS. D.G. Pfeiffer*, T.J. Boucher, M.W. Lachance (Dept. of Entomology, Virginia Polytechnic Institute & State University, Blacksburg, VA 24061), and J.C. Killian (Department of Biological Sciences, Mary Washington College, Fredericksburg, VA 22401).

Grape insects have been the subject of research in Virginia since the early 1980's. A survey of vineyardists revealed that Japanese beetle (JB), *Popillia japonica* Newman, is perceived to be the most important arthropod pest of grape. It is the target of an average of 4.2 (1-14) sprays per season. Other pests of concern are noted and discussed.

The effects of foliar feeding by JB on berry quality were studied. Vines exposed to feeding by an unrestrained population of beetles did not differ from protected vines in % soluble solids, sugar per berry, total titratable acids, pH, yield, shoot length, or leaves per vine. Higher beetle densities caged onto vines did lower fruit quality, especially after veraison.

Tunneling by ambrosia beetles (AB) and bostrichids into vine trunks and canes releases copious sap flow from wounds. A survey of these beetles revealed a complex of AB present in vineyards. Further research on the biology and control of these species is discussed.

Phenology of grape root borer (GRB), *Vitacea politiformis* (Harris) and grape berry moth (GBM), *Endopiza viteana* Clemens were monitored using pheromone traps. GRB males were active from late June to late September. GRB has not been a problem in most vineyards, but is expected to increase in importance as vineyards become established. GBM was present only at low levels; there is apparently a bivoltine population.

MANAGEMENT OF INSECT PEST POPULATIONS IN A DEVELOPING COOL CLIMATE GRAPE INDUSTRY. W. W. Cone*, L. C. Wright and M. M. Conant. Irrigated Agriculture Research and Extension Center, Washington State University, Prosser, Washington 99350.

The insect and mite pest complex for *Vitis labrusca* and *Vitis vinifera* are described for the Columbia Plateau region of the northwestern U.S. The planting and production of *V. vinifera* in this region has increased 15 fold in the last two decades. Many pest species associated with grape production in other regions are not present. Possible reasons for this will be discussed. Management strategies for some of the major pest species will be discussed including determination of economic injury levels, sequential sampling, and the use of entomogenous nematodes and parasitic wasps. The results of field experiments for control of several pests will be presented and discussed.

THE EVOLUTION OF LEAFHOPPER AND SPIDER MITE MANAGEMENT IN THE WESTERN UNITED STATES. L.T. Wilson and D. L. Flaherty, Department of Entomology, University of California, Davis, California, USA 95616, and University of California, Cooperative Extension, Visalia, California 93291

The recent introduction of the variegated leafhopper, *Erythroneura variabilis*, into the San Joaquin Valley of California has complicated the management of the congeneric grape leafhopper, *Erythroneura elegantula*, and of other pests; most noticeably two species of spider mites. Increased government restrictions on the use of insecticides, and the increasing concern over health and environmentally related issues has contributed to the need for a major reassessment of our management of grapes in California. As a result, several alternate management approaches are being investigated including the use of rootstocks, which support lower leafhopper populations; resistant management, which prolongs the field life of available insecticides; various cultural management techniques which either reduce the survival or leafhoppers in the vineyards, or reduce the attractiveness of vines; and the use of classical biological control to introduce and establish additional biotic agents. Results to date suggest that a combination of these factors could greatly reduce the need for chemical intervention and reduce the incidence of management problems that are associated with over reliance on the use of pesticides. As with any modification to a system, various adjustments will be required for the proposed changes to be successfully incorporated.

GRAPE INSECT PEST MONITORING AND IPM IN THE MISSOURI OZARKS. H.G. Townsend, State Fruit Experiment Station, Southwest Missouri State University, Mountain Grove, Missouri 65711.

Vineyards in the Missouri Ozarks are typically small and are usually located adjacent to or near wooded areas which contain large numbers of wild grapevines. Thus a large and varied complex of insect pests exists. The major pests are the grape berry moth (*Endopiza viteana* Clemens), grape phylloxera (*Daktulosphaira vitifoliae* (Fitch)), and grape root borer (*Vitacea polistiformis* (Harris)). Monitoring is done by grower scouting and sex pheromone traps. The life histories of berry moth and root borer under Missouri conditions are discussed, and the spread of phylloxera through a vineyard is illustrated.

The acceptance of IPM has been slow and consists mainly of eliminating some early season insecticide applications when pest populations are low or absent. Heavy disease pressures dictate the use of a large number of fungicide applications and many growers are content to add insecticides whenever they spray. This attitude may soon change as the Endangered Species Act is enforced, for many vineyards are located in the 28 counties where pesticide use will be restricted.

BIOLOGICAL CONTROL OF WESTERN GRAPELEAF SKELETONIZER (WGLS) HARRISINA BRILLIANS B & MCD (PYROMORPHIDAE:LEPIDOPTERA) WITH A GRANULOSIS VIRUS IN CALIFORNIA. V. M. STERN. Dept. of Entomology, Univ. of California, CA 92521.

The WGLS, *H. brillians* was introduced into southern Calif. in 1941. Two parasites of WGLS *Apanteles harrisinae* Meus. & *Sturmia harrisinae* Coq. were introduced & HbGV unknowingly brought to southern Calif. This leaf feeder requires repeated chemical treatments. HbGV acts as a classical biological control agent. I found that female and male moths that survive a low degree of infection in their larval stage are virus carriers. Infected females transmit HbGV to the offspring. Infected male moths transmit HbGV to healthy females during mating. Egg production is reduced 60 percent. Larval mortality is 90 percent. HbGV transmission continues from one generation to the next. WGLS moths are not strong fliers. Spread of HbGV is very slow. We started spraying HbGV on very small acreages in 1980 with excellent success. Eventually HbGV will spread through California.

FRENCH PRUNE TREES: A REFUGE FOR ANAGRUS EPOS GIRAULT (HYMENOPTERA: MYMARIDAE) AN IMPORTANT NATURAL ENEMY OF GRAPE LEAFHOPPERS, ERYTHRONEURA ELEGANTULA OSBORN (HOMOPTERA: CICADELLIDAE) IN CENTRAL CALIFORNIA. C.H. Pickett*, L.T. Wilson, Department of Entomology, University of California, Davis, California, 95616; and D.L. Flaherty, Cooperative Extension, University of California, County Civic Center, Visalia, California, 93291.

Vineyards planted near riparian habitats in central California seldom require control measures for grape leafhoppers, an important pest of grapes. *A. epos*, which is largely responsible for preventing late season buildup of grape leafhopper, overwinters on the blackberry leafhopper, *Dikrella californica* (Lawson) associated with blackberry bushes in this habitat. The more distant the vineyard from riparian habitats the greater the number of grape leafhoppers on vines. We have found that *A. epos* is able to overwinter on the prune leafhopper, *Edwardsiana prunicola* (Edwards). More importantly, vineyards distant from riparian habitats yet next to commercial French prune orchards, experience high early season populations of *A. epos*. Recent studies involving an experimental refuge of French prune trees in central California indicate that this refuge may aid in the early season establishment of *A. epos* populations in a companion vineyard.

GRAPE-VINES MEALYBUG PLANOCOCCUS FIGUS SIGNORET AND ITS NATURAL ENEMIES IN ARID AREAS OF CENTRAL ASIA. S.N. Myartseva, Institute of Zoology, Turkmenian Academy of Sciences, Engels Str. 6, Ashkhabad, 744000, USSR.

In the South-West of Central Asia, in the Turkmenistan, grape-vines mealybug *P. ficus* occupies more often fig-trees, pomegranates and vines. Particularly it damages fig-trees and vines. *P. ficus* has 4-5 generations for a year. The complex of parasitoids and predators, which develop on *P. ficus*, includes 12 species from 5 orders of Insecta - Hymenoptera, Diptera, Coleoptera, Neuroptera and Hemiptera. Parasitoids *Anagrus pseudococci* Gir. (Encyrtidae) and *Allothropa mecrida* Walk. (Platygastridae) are unspecialized. Predators are 12 species from Coccinellidae (7), Chrysopidae (1), Chamaemyiidae (1) and Anthocoridae (3). From them two species of lady-birds from genus *Scymnus*, *Hyperaspis polita* Ws., lace-wings *Chrysopa carnea* Steph. and silver-fly *Leucopis alticeps* Cz. are found more often in foci of *P. ficus*. *Anagrus pseudococci* is the most effective parasitoid of this mealybug. It parasitizes 70 per cent grape-vines mealybug. Predators are less effective.

STATUS AND MANAGEMENT OF GRAPE MEALYBUG *Maconellicoccus hirsutus* (GREEN) IN ANDHRA PRADESH. K.M. AZAM* AND T. RAMESH BABU, Department of Entomology, A.P. Agricultural University, Rajendranagar, Hyderabad-500030, India.

Grape production is hampered due to serious attack of mealybug, *Maconellicoccus hirsutus* (Green) in several states of the country. The losses are more conspicuous subsequent to winter pruning (78%) than after summer pruning (58%).

The sticky substances viz., Tack-trap and Bird Tangle foot were found to reduce 50% of the mealybug infestation. Dipping of infested bunches for two minutes in phosalone with fish oil rosin soap, garlic oil alone and monocrotophos with fish oil rosin soap, were found to be effective in controlling the mealybug population.

Release of the predator, *Cryptolaemus montrouzieri* Mulsant on grape mealybug, *M. hirsutus* at 20 beetles/vine or 6 larvae/bunch was found to reduce mealybug infestation by 62% and 78% respectively. The technique developed for rearing and releasing 10,000 beetles which would be sufficient to control the mealybug in one hectare was estimated to cost \$ 72. The pupae of the predator can be stored for a period of 20 days by exposing the five day old pupae to 10°C temperature for 3 weeks without having any adverse effect on the fecundity of the resulting adults.

LEAF INFESTATIONS OF OLCYCLIC VITEUS VITIFOLIAE (FITCH) (GRAPE PHYLLOXERA) ON EUROPEAN VINES. V. Girolami*, A. Strapazzon, Department of Plant Protection, University of Udine, 33100 Udine, Italy.

Leaf infestations of grape phylloxera have been frequently observed in Italy on grafted European vines during the last ten years. Populations originating from the offspring of overwintering eggs have been observed.

Observations on the flight of sexuparae during the last 6 years, on leaf and root infestation dynamics in commercial vineyards, on the influence of varieties of European vines and on the relationship between leaf infestation and grape quality have been reported.

INFLUENCE OF FUNGICIDES AND DIFFERENT ROLE OF KAMPIMODROMUS ABERRANS (OUD.) AND AMBLyseius ANDERSONI (CHANT) ON THE CONTROL OF SPIDER MITES IN VINEYARDS. V. Girolami*, C. DUSO, Institute of Entomology, University of Padua, 35131 Padova, Italy.

The toxicity of fungicides on phytoseiid mites represents the main factor of imbalance in spider mite populations. The repeated use of dithiocarbamates causes frequent infestations of spider mites independently of the cultural practices and the use of insecticides.

A. andersoni is the most widely spread phytoseiid in northern vineyards where insecticides and dithiocarbamates are used.

The control of P. ulmi and E. carpini by A. andersoni often proves to be unsatisfactory. Neither has the release of this predator been successful. On the contrary, the release of K. aberrans is easy and leads to a permanent control of spider mites. However, this species proves particularly susceptible to dithiocarbamates. These fungicides can be substituted without increasing costs.

USAGE DU FLUFÉNOXURON PERTURBATEUR DE LA CROISSANCE DES INSECTES POUR UNE NOUVELLE APPROCHE DE LA LUTTE CONTRE LES TORDEUSES DE LA GRAPPE (LOBESIA BOTRANA SCHIFF ET EUPOECILIA AMBIGUELLA HB) ET LES ACARIENS PHYTOPHAGES (EOTETRANYCHUS CARPINI OUDEMANS ET PANONYCHUS ULMI KOCK). H. Marcelin*, Institut Technique de la Vigne et du Vin (ITV), Maison de l'Agriculture, 66025 Perpignan, France, Ph. Debray, Agrishell, 14, chemin du Professeur Depéret, 69160 Tassin La Demi Lune, France.

Le flufénoxuron, nouvel acyl urée perturbant la croissance des insectes et des acariens, a fait l'objet d'une approche inédite de la protection du vignoble. Cette évaluation sur les tordeuses de la grappe par intervention préventive avant toute éclosion des oeufs, montre qu'à faibles doses, le flufénoxuron permet en pratique une lutte efficace tout en offrant souplesse d'emploi et effet secondaire sur les acariens. Son efficacité acaricide est mise en valeur sur des populations en début d'installation. Le flufénoxuron peut largement contribuer à une stratégie de lutte par protection précoce contre ces importants ravageurs du vignoble européen.

DEVELOPMENT OF LOW SPRAY, BIOLOGICAL, AND PHEROMONE APPROACHES FOR CONTROL OF GRAPE BERRY MOTH, ENDOPIZA VITEANA CLEMENS, IN THE EASTERN UNITED STATES. T. J. Dennehy*, C. J. Hoffman, and M. C. Saunders, Departments of Entomology, Cornell University, NYS Agric. Expt. Stn., Geneva, NY, USA, 14456 and The Pennsylvania State Univ., University Park, Pennsylvania, USA, 16802.

Grape berry moth is the primary arthropod pest of commercial grape production in the Eastern United States. Research on integrated management strives to reduce insecticide usage in vineyards by providing alternatives to calendar-based prophylactic treatments for this pest. Research conducted in New York and Pennsylvania has centered on development of tactics of assessing risk of GBM attack in vineyards and characterization of the causal factors responsible for differences between high- and low-risk vineyards. Sampling procedures and thresholds have been developed and validated. Use of improved timing and minimal number of insecticide treatments and use of pheromones for mating disruption has been evaluated to reduce insecticide usage and enhance natural enemy effectiveness in vineyards. Interactions between GBM and bunch rot of grapes are characterized to adjust action thresholds for cultivars prone to have bunch rot problems.

THE USE AND SIGNIFICANCE OF EXPERT SYSTEMS IN MANAGEMENT OF PESTS OF SMALL FRUITS. M. C. Saunders*, and E. G. Rajotte, Department of Entomology, The Pennsylvania State University, University Park, Pennsylvania, USA, 16802.

The complexity of the numerous pest management problems associated with small fruit production, the need for immediate response to perceived problems, and the relative scarcity of local expertise necessitates the development of decision support tools that provide growers with timely, accurate, and accessible information. Expert systems offer a method to transfer the knowledge of experts to farm managers. An expert system is a computer system designed to simulate the problem-solving behavior of a human expert. Expert systems technology can be used to capture the problem solving logic of experts in a number of agricultural subject areas to provide decision support in an integrated fashion. At The Pennsylvania State University, expert systems are being developed for several fruit crops that incorporate the expertise of entomologists, pathologists, horticulturists, and economists. These expert systems rely heavily on graphics to help with data acquisition and with explaining the reasoning behind a recommendation.

PRINCIPLES AND CONCEPTS FOR I.P.M. IN FLORICULTURE CROPS. M. P. Parrella, Department of Entomology, University of California, Riverside, CA 92521.

Growers of ornamental crops have traditionally relied on pesticides as their major method of pest control. Problems with pesticide resistance, cost, availability of materials and increasing rules and regulations governing pesticide use have caused growers to begin to explore alternative methods of pest control. Unfortunately, the technology for IPM in floriculture crops is not there for growers to adopt. Extrapolation of IPM methods developed for other crops to a floriculture crop usually results in failure and a discouraged grower. The concept that IPM methods must be superior to chemical control will hinder research/extension efforts directed at implementation; the goal should be equivalency with chemical control. This can be achieved through an IPM program attuned to that particular crop and greenhouse situation.

AN IPM PROGRAM FOR LARGE-SCALE CHRYSANTHEMUM PRODUCTION IN COLOMBIA. F. Jaramillo, Gardens of the Andes, Apartado aereo 4277, Bogotá, Colombia, South America.

Chrysanthemum production at Garden of the Andes in Bogotá which encompasses 40 ha. These cut flowers are destined primarily for the export market so no pests can be tolerated on the finished product. Major pests include the leafminer, *Liriomyza trifolii* (Burgess), and aphids (*Myzus persicae* Sulzer and other species). Problems are increasing with flower thrips (*Frankliniella* spp.). The IPM program used is designed to maximize efficacy of insecticides through proper selection and timing of sprays. This is accomplished with elaborate sampling systems using yellow sticky cards in and outside the greenhouses as well as through extensive monitoring of environmental conditions. Several parasite species are currently being evaluated for their leafminer control capability. These are being used and monitored in weedy areas adjacent to the chrysanthemum production facilities. Pesticides are vital for proper pest control and every effort is made to use only those materials with full U.S. Environmental protection Agency registration.

CULTURAL AND PESTICIDAL RECOMMENDATIONS FOR MANAGEMENT OF SWEETPOTATO WHITEFLY, *BEMISIA TABACI* (HOMOPTERA: ALEYRODIDAE), IN FLORIDA'S FLOWER CROPS. James F. Price*, University of Florida, IFAS, Gulf Coast Research and Education Center, 5007 60th Street East, Bradenton, FL 34203 and Bernie Janssen, Department of Entomology, Wageningen Agricultural University, Postbox 8031, Wageningen 6700 EH, The Netherlands

In fall 1986 sweetpotato whitefly infested numerous of Florida's greenhouse and field grown ornamental and vegetable crops, including poinsettia, gerbera daisy and hibiscus. The whitefly is now distributed throughout the state but most flower crops can be produced without significant yield and quality losses. Recommended management programs include planting pest free stock known to be least susceptible to attack, eliminating certain weed hosts from production environs, providing host free periods between susceptible crops, scouting for early detection of various life stages and applying pesticides found to be effective against specific life stages present.

MANAGEMENT OF INSECT VECTORS OF PATHOGENS IN FLORICULTURAL CROPS. A.B. Broadbent, Agriculture Canada, Vineland Station, Ontario, Canada L0R 2E0.

Control of insect-transmitted pathogens of greenhouse ornamental crops requires an integrated approach. The tomato spotted wilt virus (TSWV), which has reached epidemic levels in greenhouse crops (eg. gloxinia, impatiens, cyclamen and chrysanthemum) in many parts of the world, is best managed by controlling its thrips vector (including cultural, chemical and biological methods) and by excluding and eradicating the virus. In greenhouses in eastern Canada, the western flower thrips, *Frankliniella occidentalis* (Pergande), has displaced the eastern flower thrips, *F. tritici* (Fitch), and onion thrips, *Thrips tabaci* Lindeman, in recent years. *F. occidentalis* is an efficient vector and the dominant species in Canadian greenhouses.

Bacterial leafspot, *Pseudomonas cichorii* (Swingle) Stapp., of chrysanthemum can be transmitted on the body of *Liriomyza trifolii* (Burgess). The bacterium enters leaf tissue through wounds caused during oviposition and feeding. As these wounds age they become less susceptible to infection. In contrast to TSWV, the epidemiology of bacterial leafspot is greatly dependent on environmental factors. Management of *L. trifolii* on chrysanthemum also requires the integration of cultural, chemical and biological controls.

CONSIDERATIONS SUR LES POSSIBILITES DE LUTTE BIOLOGIQUE ET INTEGREE CONTRE LA MOUCHE MINEUSE, *LIRIOMYZA TRIFOLII* (BURG.), DANS LA CULTURE PROTEGEE DE GERBERA EN ITALIE. Vacante V., Calabretta C., Nucifora A. (*), Istituto di Entomologia agraria - Università - Via Valdisavioia, 5 95123 Catania (Italy)

Les Auteurs examinent le problème de la mouche mineuse, *Liriomyza trifolii* (Burgess) (Diptera, Agromyzidae), dans les cultures protégées de gerbera en Italie et exposent quelques considérations sur les possibilités de lutte biologique et intégrée contre le phytophage, expérimentées avec succès en Italie. Les cultures de gerbera sont très recherchées par ce diptère. Les dégâts relevés sur la gerbera fréquemment très important, peuvent obliger l'agriculteur à affectuer un nombre considérable de traitements chimiques. En ce qui concerne la lutte contre les adultes, la méthode chromatographique, basée sur l'emploi des pièges jaunes englués a été testée avec succès. Contre les larves l'avermectin B1, à la dose de 0,9 g/hl d'eau, a détruit 80% des larves, sa rémanence oscille entre 10 et 14 jours. Il a une forte action acaricide. Parallèlement aux études sur la lutte chimique et chromatographique, le chercheur a permis la découverte des Eulophides *Diglyphus isaea* (Walker), *D. minoensis* Walker, *Chrysotoxum formosa* (Westwood), *Pediobus* sp., *Pnigalio* sp. et du Braconide *Dacnusa sibirica* (Telenga). En Sicile, *D. isaea* est l'entomophage le plus actif; il peut neutraliser environ 90% des larves. La lutte biologique représente la méthode de défense la plus convenable.

REGULATION OF SPIDER MITE POPULATION WITH *PHYTOSEIUS PERSIMILIS* A.-H. AND THE IMPACT OF POPULATION ON DEVELOPMENT OF THE PLANT.

D. Kropczyńska*, A. Tomczyk, B. Czajkowska, Department of Applied Entomology, Warsaw Agricultural University, 02-766 Warsaw, Nowoursynowska 166, Poland.

Feeding of spider mites can stimulate the growth and flowering of infested plants. This phenomenon takes place when moderate numbers of spider mites feed for a relatively short period of time or if a few mites feed for a long period. Experiments were carried out to manipulate the mite density and period of mite feeding on chrysanthemums. *Phytoseiulus persimilis* was used to regulate population of the pest during the whole growing season.

WHY IS INTEGRATED PEST CONTROL IN FLORICULTURE IN GREENHOUSES SO UNPOPULAR? J.C. van Lenteren, Department of Entomology, Agricultural University, Wageningen, the Netherlands.

The total world area covered by greenhouses is approximately 150.000 ha. Ornamental crops are grown on about 50% of this area. Although developments in biological and integrated control of pests in greenhouse vegetables have been spectacular during the past 20 years, the spinoff for ornamentals has been little. Natural enemies are applied on some 5000 ha of greenhouses worldwide, only 20 ha consist of flowers. The zero tolerance, even for any signs of damage, used in flowers for export seems to inhibit use of biological control agents. Biological control is applied only -but with good success- in greenhouses with non export flowers, in botanical gardens and interior landscapes. Increasing pesticide resistance problems, increasing costs of chemical treatments, and a change in the zero-tolerance export policy will lead to an increase in use of IPM in some ornamental crops. Breeding for host-plant resistance against insects and mites is another way to stimulate development of IPM programs. The most important cornerstone for successful development of IPM is, however, a non-scientific factor: the will of policy makers, researchers, advisory workers and growers to change from pure chemical to integrated pest control.

PEST MANAGEMENT IN FOLIAGE CROPS. L. S. Osborne, University of Florida, Central Florida Research and Education Center, Apopka, 2807 Binion Road, Apopka, FL 32703. USA.

Pest management systems for foliage plants is accomplished almost exclusively with pesticides. Research is being conducted to manage the use of pesticides. This includes studies to determine the effects these materials have on all aspects of plant production. Methods are being developed to make more efficient use of pesticides and minimize resistance development. A major thrust at the CFREC-Apopka Research Center is to develop biological control programs for such major pests as *Tetranychus urticae*, *Bemisia tabaci*, aphids, and mealybugs.

CONCEPTS FOR EXCLUSION OF PEST ARTHROPODS ON EXPORT FLOWER CROPS. M. van de Vrie (Netherlands)

No Abstract

THE APPLICATION OF PEST MANAGEMENT SYSTEMS IN INTERIOR PLANTSCAPES. M.Y. Steiner. Alberta Environmental Centre, Vegreville, Alberta, Canada T0B 4L0.

Integrated pest management has been used in interior plantscapes for several years with varying degrees of success. The concept is readily accepted by growing numbers of professionals and technicians in the industry. In practice it is inhibited by a lack of commercial supplies of some key beneficial organisms and inconsistent production of others. Data is presented on the effectiveness of several of the key organisms, with a discussion of the problems and benefits of their use. Recognition is also made of the need for integration with pesticides, management practices and choice of plant material in gaining wider acceptance of this approach to pest control in interior plantscapes.

IMPLEMENTATION OF PEST MANAGEMENT ON A LARGE SCALE CHRYSANTHEMUM FARM. D. L. Warkentin, Technical Business Group, Yoder Brothers, Inc., P.O. Box 68, Alva, Florida, 33920.

Virtually all of the vegetative chrysanthemum cuttings produced in the United States are propagated in open-field shade houses in southern Florida by Yoder Bros., Inc. Insect and disease pest management is driven by (1) low tolerance for pest presence and/or damage, and (2) high per unit value of the managed crop.

Pest management efforts may be described in terms of an information flow among three principle divisions of the company: Operations, Research & Development, and Sales/Service. Within Operations preventative pest control programs are implemented, and therapeutic action is carried out in direct response to reports from growers and pest scouts. The continuing pest control needs of Operations are communicated to R&D; R&D then develops integrated programs and submits recommendations back to Operations. The concerns of customers are expressed through Sales/Service, and appropriate control recommendations are supplied by R&D.

The system is illustrated by several examples involving important chrysanthemum pests.

DELIVERY OF IPM SYSTEMS IN FLORICULTURE TO GROWERS: AN EXTENSION VIEWPOINT. L. R. Wardlaw, ADAS, MAFF, Olantigh Road, Wye, Ashford, Kent, England TN25 5EL and J. Reitzel, C. Hansen's Biosystems, Bøge Alle 10-12, 2970 Hørsholm, Denmark.

Increasing resistance of pests to insecticides has created a situation where it may not be possible to grow some protected crops in future unless these pests are controlled. Although IPM is well-established practice on edible crops, there is a serious threat to these from newly resistant pests that can spread from ornamental crops. The threat is even more serious if the pests transmit viruses.

IPM systems can work well in floriculture but there may be problems due to the need for blemish-free produce. Using IPM programs that provide "economic overkill" of pests by regular introductions of natural enemies may help to solve some of the problems. Education to alter attitudes of growers and the general public is a fundamental necessity for successful IPM in floriculture.

INTEGRATED PEST MANAGEMENT OF ANTHURIUM. A.H. Hara* and W. T. Nishijima, Beaumont Agricultural Research Center, Univ. of Hawaii, 461 West Lanikaula St., Hilo, Hawaii 96720.

As an initial step in developing an IPM program for anthuriums, causes of flower rejection were determined at farms. In general, insects, mites and diseases caused very little rejection compared to noninfectious causes. Flower rejections increased during June through November and decreased during December through May. Monitoring techniques were developed for the anthurium thrips, Chaetanaphothrips orchidii; the false spider mites, Brevipalpus spp.; the black twig borer, Xylosandrus compactus; the anthurium whitefly, Aleurotulus sp.; anthracnose, Colletotrichum gloeosporioides; and the bacterial blight, Xanthomonas campestris pv. dieffenbachiae. IPM and grower plots were established at three cooperating farms. Plots were monitored for pests and diseases once every two weeks and control measures implemented only as required for the IPM plots while the grower plots were sprayed on a calendar basis. During the first year the three growers had a total of 61 pesticide applications, while IPM plots had a total of 26 pesticide applications to maintain the same level of pest control. These results indicate that the IPM program of anthuriums can decrease the use of pesticides, thus decreasing the cost of production and ultimately making anthurium production safer for growers and the environment.

COLORADO POTATO BEETLE MANAGEMENT STRATEGIES. David N. Ferro, Department of Entomology, University of Massachusetts, Amherst, Massachusetts 01003, USA.

The Colorado potato beetle, *Leptinotarsa decemlineata* (Say) is managed world wide by a number of strategies. Insecticides continue to be the most widely used method of controlling *L. decemlineata*. However, non-insecticidal approaches, such as crop rotation, plant resistance and biological control should play a more important role in the future. In North America, the egg predators *Coleomegilla maculata*, and *Lebia grandis* are important agents in certain areas. The tachinid larval parasite *Myiopharus doryphorae*, is abundant in many areas where *L. decemlineata* is a pest. Most of these endemic natural enemies are in low numbers in commercial potato production areas because of the heavy use of insecticides. A new strain of *Bacillus thuringiensis* (var. *san diego* and *tenebriones*) has been shown to be effective in the field and could be an important management tool to reduce *L. decemlineata* populations without killing its natural enemies. The agents when used with crop rotation should allow for a major reduction in the use of insecticides for controlling *L. decemlineata*.

SEASONAL PHENOLOGY OF THE COLORADO POTATO BEETLE IN NEW YORK. C. A. Tauber and M. J. Tauber, Department of Entomology, Comstock Hall, Cornell University, Ithaca, New York 14853-0999.

In comparing two populations of the Colorado potato beetle from climatically different areas in New York State, we found that the thermal regulation of preimaginal development did not differ significantly between those from a warm, coastal area (Long Island) and those from a cool, inland area (Upstate). But females from the Long Island population generally oviposited fertile eggs at lower temperatures than the females from Upstate. Immatures from a single egg mass, especially those from Long Island, showed considerable variation in developmental rates under field conditions.

The two populations differ in their responses to factors that influence voltinism. For the induction of aestival diapause, the critical photoperiod is longer and the influence of temperature is greater in the Upstate population. In both populations, a large proportion of first generation adults enter diapause without ovipositing or after ovipositing briefly.

The intensity of diapause has a distinct seasonal pattern in both populations. However, the Long Island population has a less intense diapause. Both populations have similar thermal thresholds for the initiation of reproductive development after dormancy, but the Long Island population has lower thermal requirements for the initiation of oviposition.

MODIFICATION OF RICHARD AND WALOFF'S SECOND METHOD TO CALCULATE STAGE SURVIVAL, WITH APPLICATION TO THE COLORADO POTATO BEETLE, *LEPTINOTARSA DECEMLINEATA* (SAY) (COLEOP.: CHRYSOMELIDAE). R.G. Van Driesche*, T.S. Bellows, D.N. Ferro, R. Hazzard, M. Maher, and R. Voss. Department of Entomology, Fernald Hall, Univ. of Massachusetts, Amherst, MA, USA, 01003.

Stage survival is typically calculated by reference to estimates of numbers entering two successive life stages. We present a modification of Richard and Waloff's Second Method that estimates stage survival by reference to the difference between the sum of directly measured recruitment to the stage and the estimate of numbers entering the stage derived from the application of Southwood and Jepson's graphical method to stage frequency counts of the stage of interest. The method assumes a constant mortality rate with respect to age within the stage but examines the severity of the bias if the assumption is not met. The method is applied to four generations of the egg stage of the Colorado potato beetle, *Leptinotarsa decemlineata* (Say) (Coleop.: Chrysomelidae) and the predicted stage survivals, for two generations only, are compared against direct field measurements of egg mortality. The method's predictions for all four generations are further compared to simulations from a computer model of the Colorado potato beetle. The method has special utility where stages subsequent to the ones of interest cannot be quantified due to dispersal or arbitrary losses, as due to pesticides.

RESISTANCE DETECTION AND MANAGEMENT IN THE COLORADO POTATO BEETLE. R.T. Roush*, Department of Entomology, Comstock Hall, Cornell University, Ithaca, NY 14853-0999, USA and G.G. Kennedy, Department of Entomology, North Carolina State University, Raleigh, NC 27650, USA.

Topical assays seem to be at least as efficient for monitoring resistance in adult Colorado potato beetles (CPB) as residual assays, but residual assays show promise for monitoring for resistance in young larvae. Field applications of azinphosmethyl, endosulfan, carbofuran and fenvalerate can be simulated on potato plants in the laboratory. The survival on these treated plants of second through fourth instar larvae from resistant (Long Island) and susceptible (Iowa) strains correlates closely with the resistance measured in the adults of the same strain. The use of these monitoring techniques for the management of resistant CPB will also be discussed.

GEOGRAPHIC VARIATION IN HOST PLANT ADAPTATION OF THE COLORADO POTATO BEETLE. T. H. Hsiao, Department of Biology, Utah State University, Logan, Utah 84322-5305, U. S. A.

The host plant range of the Colorado potato beetle, *Leptinotarsa decemlineata*, has expanded considerably since it adapted to the cultivated potato and subsequently spread throughout North America and continental Europe. Some 15 native and introduced species of Solanaceae have now been recorded as hosts. Geographic populations show a wide range of host plant affinity. Populations on native *Solanum* hosts from southern Mexico are nearly monophagous while those feed on cultivated hosts are oligophagous. Several beetle populations showed host plant adaptation as evidenced by superior growth and reproduction on their respective hosts. Cross-breeding experiments revealed that the genetic mechanism of host adaptation probably involves polygenic traits. Behavioral studies indicated that beetle populations from cultivated hosts can feed on more plant species because of their greater tolerance to deterrent qualities of plants. The availability of more hosts in cultivated fields appears to favor the development of less fastidious beetles that are also more fecund and vigorous. The adaptability of the Colorado potato beetle will continue to be an obstacle to breeding resistant crop varieties as a pest management strategy.

COLORADO POTATO BEETLE RESISTANCE IN VEGETABLE CROPS: POTENTIAL CONTRIBUTIONS FROM GENETIC ENGINEERING. S.L. Sinden*, L.L. Sanford and K.L. Deahl, Vegetable Laboratory, USDA/ARS, Beltsville, MD 20705.

Host plant resistance could become an important component of IPM systems for controlling the beetle if resistant cultivars were available. Although high levels of resistance have been found in wild *Solanum* species, progress in breeding resistant cultivars has been slow. Crossing barriers sometimes prevent sexual hybridizations between wild species and their crop relatives. In some cases, genes for resistance may be linked to genes for undesirable horticultural traits in the wild species, presenting major obstacles to the development of resistant cultivars by conventional breeding.

The new gene transfer techniques such as protoplast fusion and plant transformation with cloned genes can perhaps aid the breeder in transferring resistance into crop cultivars. We are presently attempting to transfer the leptine glycoalkaloids from nearly immune *S. chacoense* plants to potato by protoplast fusion. In the near future, it may be possible to clone genes for resistance factors, such as leptines and glandular trichomes, which are controlled by only a few genes. The genes could then be transferred directly into popular cultivars by protoplast electroporation or the Ti plasmid vector.

COLORADO POTATO BEETLE MODEL: APPLICATION TO MANAGEMENT STRATEGIES. J.A. Logan*, R.H. Voss, D.N. Ferro, and M. Sears, Natural Resource Ecology Laboratory, Colorado State University, Fort Collins, CO 80523, USA.

In this paper we discuss the biological basis and mathematical structure of a Colorado potato beetle model. This model has recently been expanded to represent the seasonal spatial dynamics of the beetle. Additionally, an option is provided which allows the user to sample the simulated population and make adaptive decisions regarding control strategies. This latter modification has increased the heuristic value of the model as an instructional aid, and additionally has significantly increased the power of the model as an adaptive management tool. The original model is currently embedded as part of a highly interactive, graphically-oriented, menu-driven management simulator. The potential for this program to serve as a basis for a Colorado potato beetle decision support system is discussed in detail.

BIOLOGICAL OBSERVATIONS ON *EDOVUM PUTTLERI* GRISS. (HYM.: EULOPHIDAE) INTRODUCED IN ITALY AGAINST THE COLORADO POTATO BEETLE. F. Bin* and S. Colazza, Agric. Entomology Inst., Perugia Univ., Borgo XX Giugno, 06100 Perugia, Italy.

In November 1985, the oophage *E. puttleri* was introduced in Italy from United States (first introduction in Europe) to control *Leptinotarsa 10-lineata* and preliminary laboratory and field observations have been carried out.

Results are given on the following aspects: some host egg characteristics, specificity tests, parasitoid longevity and fertility in relation to different diet combinations, other aspects of the host-parasitoid relationship and behavioral parameters measured in the field (searching, exploitation and control efficiency).

USE OF *EDOVUM PUTTLERI* IN AN IPM SYSTEM FOR COLORADO POTATO BEETLE IN EGGPLANT. James H. Lashomb, Box 231 Cook College Putgero University, New Brunswick, Nova Scotia 08903, Canada.

An IPM system emphasizing *Edovum puttleri* Grissell in eggplant for suppressing annual populations of Colorado potato beetle is discussed. Release and evaluation strategies for manipulating the wasp in the field will be presented.

EDOVUM PUTTLERI GRISSSELL: TRIALS IN LABORATORY AND IN BIOCONTROL OF COLORADO POTATO BEETLE ON EGGPLANT. S. Maini*, G. Nicoli and M. Benuzzi, Istituto di Entomologia "G. Grandi", Università, Via F. Re, 6, 40126 Bologna, Italy.

Edovum puttleri (Hymenoptera: Eulophidae) parasitization and host feeding were laboratory tested on normal or cold-devitalized *Leptinotarsa decemlineata* (Say) (Coleoptera: Chrysomelidae) (CPB) eggs. Both egg types, although frozen to a lesser extent, allowed full offspring development. Results showed that 50% of the females can survive over 30 days on CPB eggs and honey (16-8 photoperiod; 27-20°C thermoperiod; 80% RH). Female activity was studied as a function of age. In northern Italy CPB, especially in the larval stage, causes major damage to eggplant, a cash crop in the region. The insecticides normally used against CPB prevent effective biocontrol with *Encarsia formosa* Gahan and *Phytoseiulus persimilis* Athias-Henriot. In 1986 preliminary trials were conducted in which reared CPB were induced to oviposit on plants at scattered points in a greenhouse. Parasitoids were then released at a given point to determine their host finding ability. In 1987 trials were conducted throughout the natural CPB infestation period in two plots, i.e. plastic-sheeted tunnel and open field, at a release rate of 0.9-1.8 adults/m² weekly (sex ratio 3:1). All the CPB egg masses were labelled twice weekly and later taken to the laboratory to check parasitization and predation. Inundative releases of *E. puttleri* may be a promising biocontrol technique.

INTEGRATION OF *EDOVUM PUTTLERI* GRISSSELL IN IPM SYSTEMS FOR COLORADO POTATO BEETLE CONTROL ON POTATO AND TOMATO CROPS. R.F.W. Schroder*, USDA, ARS, PSI, BIL, Beltsville, MD 20705, and M.M. Athanas, Department of Entomology, University of Maryland, College Park, MD 20742 U.S.A.

Edovum puttleri (EP) utilized in a potato IPM system, parasitized 50-55% of the Colorado potato beetle (CPB) egg masses. EP significantly reduced second generation CPB larvae. The use of the herbicides Devrinol and Sencor do not adversely affect EP in the field. EP released on tomatoes, parasitized 14-58% of the CPB egg masses. Demonstrated that EP is best utilized in IPM systems that provide early season chemical control of emerging overwintered CPB. Research shows biocontrol can work in high value crops.

BIOLOGICAL CONTROL STRATEGIES FOR COLORADO POTATO BEETLE IN NORTHWESTERN USA. K. Duane Biever, USDA, ARS, Yakima Agric. Res. Lab., 3706 W. Nob Hill Blvd., Yakima, WA 98902, USA.

In Northwestern USA, Colorado potato beetle (CPB) populations are presently controlled by insecticides. Research is being conducted to develop management strategies that suppress CPB populations while effectively integrating with management approaches for the green peach aphid. Our program emphasizes the use of beneficial agents to regulate both pests.

Most overwintering CPB are found 20-40 cm below the soil surface and they may have a prolonged diapause of up to 5 years. Cage studies established that the parasite, *Myiopharus doryphorae*, does not overwinter in the soil. The predator, *Perillus bioculatus*, can be continuously reared in the absence of CPB on *Trichoplusia ni* and release of *P. bioculatus* and *Podisus maculiventris* (cage studies) reduced populations of CPB by 50%. Field tests with *Beauveria bassiana* established its potential (65% reduction) as a component for the management scheme and *Bacillus thuringiensis*, specific for CPB, appears to integrate well with other beneficial agents.

THE POTENTIAL FOR BIOLOGICAL CONTROL OF THE COLORADO POTATO BEETLE, *LEPTINOTARSA DECEMLINEATA* SAY (COLEOPTERA: CHRYSOMELLIDAE), BY THE PREDATOR-PARASITOID *LEBIA GRANDIS* HENTZ (COLEOPTERA: CARABIDAE), E. Groden*, D.L. Haynes, Dept. of Entomology, MSU, East Lansing, MI 48824; R.A. Casagrande, Plant Science Dept., Univ. of RI, Kingston, RI 02881.

This study was designed to evaluate the potential of the carabid *L. grandis* Hertz for biological control of the Colorado potato beetle (CPB). *L. grandis*, an endemic natural enemy, fed on all immature stages of the CPB, and was found to feed over a wide range of temperatures. Field cage studies demonstrated the potential impact of *L. grandis* adults on CPB populations and indicated a strong density dependent response by this predator. Seasonal activity patterns were determined, and in combination with laboratory development studies indicate that this species completes one generation per year in MI.

As *L. grandis* larvae are ectoparasitoids of CPB prepupae, a sampling technique was required that would reveal the pupation site of the host without dislodging the parasitoids. Releasing tethered hosts was successful, and in 1986, 18.2% (n = 170) were parasitized. In 1987, weekly parasitism levels were determined, and parasitism peaked at 42%. In MI in 1987, mortality of immature CPB in unsprayed potatoes was > 96%, and a significant portion was due to predation and parasitism by *L. grandis*. This species has considerable potential for biological control of CPB.

BIOLOGICAL CONTROL PROGRAMS OF THE COLORADO POTATO BEETLE IN THE U.S.S.R. S.S. Izhevsky (USSR)

No Abstract

POPULATION DYNAMICS OF THE COLORADO POTATO BEETLE IN MEXICO. F.A. Drummond* and D. Cappaert, Department of Entomology, Michigan State University, East Lansing, MI 48824.

The central valley of Mexico is the presumed evolutionary origin for the genus *Leptinotarsa* and the Colorado potato beetle. Since 1983, we have surveyed and studied predators and parasites associated with the Colorado potato beetle in its native habitat. General predators predominate the collections. Specific species so far evaluated for use in the northeastern U.S. are the pentatomid predator: *Oplomus dichrous* (H.S.); a biotype of the eulophid wasp, *Edovum puttleri* Grissel; and a parasitic mite, *Chrysomelobia labidomerae* Eickwort. Only the mite shows promise for an inoculative release strategy. The impact by this mite on the Colorado potato beetle is not reduced adult longevity, but rather a reduction in the distance of dispersal by flight. The potential of other predators and parasites found during the summer of 1986 will also be discussed.

MANAGING THE COLORADO POTATO BEETLE WITH *BACILLUS THURINGIENSIS* VAR. *SAN DIEGO*. W. D. Geierster, Mycogen Corporation, San Diego, California, USA 92121.

Bacillus thuringiensis var. *san diego* (B.t.sd) is a naturally occurring bacterial strain with high levels of potency against several coleopteran species including the Colorado potato beetle, *Leptinotarsa decemlineata*. Laboratory studies indicate that B.t.sd is active against all Colorado potato beetle life stages, with highest potencies observed against small (1st and 2nd instar) larvae. A procedure for quantifying B.t.sd potencies in terms of Colorado potato beetle International Units has been developed. Results from Tier 1 toxicology studies demonstrate that B.t.sd had no effect on any of the mammal, bird, fish or beneficial insect species tested. In house fly bioassays and HPLC analyses, no evidence of beta exotoxin or other teratogenic toxins was detected.

M-One™ Insecticide, a liquid formulation based on B.t.sd, was tested during 1987 on 58 commercial potato, tomato and eggplant farms. Data collected from these test sites demonstrated that M-One applications result in Colorado potato beetle control that is consistently equal to or better than that resulting from applications of conventional chemical insecticides.

FEEDING MECHANISMS IN LYGUS. O. P. Young, Southern Field Crop Insect Management Laboratory, USDA-ARS, Stoneville, MS 38701.

The feeding of *Lygus* is viewed as a multi-stage process involving search, detection, evaluation, and acceptance of food. Search behavior may be mediated by internal and/or external factors such as degree of hunger and climatic conditions. The detection of food involves both visual and olfactory cues at long distance and tactile stimuli at short distance. Tapping and probing activity by the mouthparts is part of the evaluation process that leads to eventual acceptance or rejection of the potential food plant. Interactions between the plant and the insect are also considered important. These include salivary secretions that may: (1) affect future development of the plant, perhaps to the benefit of the insect, and (2) moderate potentially toxic or deterrent substances in the plant. Various ions from plants ingested by *Lygus* may also increase digestibility of polysaccharides, lead to reduced feeding time on the plant, and thus result in reduced damage.

THE HOST PLANT RANGE OF LYGUS RUGULIPENNIS POPP. (HEMIPTERA: MIRIDAE). A.-L. Varis¹ and J. K. Holopainen², 1) Department of Agricultural and Forest Zoology, University of Helsinki, SF-00710 Helsinki, Finland, 2) Ecological Laboratory, University of Kuopio, P.O.Box 6, SF-70211, Kuopio, Finland.

European literature regarding the host plants of the tarnished plant bug (*Lygus rugulipennis* Popp.) is surveyed and records of some unpublished host plants are added by the authors. The recorded hosts include about 220 plants classified to genus, species or subspecies level. The most important host families are the Brassicaceae, Asteraceae and Fabaceae. The highest total number of recorded host plants is in the Federal Republic of Germany, Poland and Sweden. Damage to crop plants caused by *L. rugulipennis* has been most often recorded on alfalfa, cereals, clover, potato, strawberry and sugarbeet.

RESPONSE OF WHEAT TO FEEDING BY LYGUS RUGULIPENNIS POPPIUS (HEMIPTERA: MIRIDAE). A.-L. Varis* and S. Laurema, Department of Agricultural and Forest Zoology, University of Helsinki, SF-00710 Helsinki, Finland.

Lygus rugulipennis adults and nymphs were enclosed in cloth bags in the field on ears of spring wheat at the early milk ripening stage. When 2 or 5 specimens per ear were kept for about 4 weeks on the ripening wheat, the weight of the ears and grains was reduced significantly. Germination was lower and the development of sprouts grown from the injured seeds was poorer than for uninjured seeds. The effect of the females was slightly stronger than that of the males.

The results were confirmed by laboratory tests: when 1 *L. rugulipennis* male or female was allowed to feed on a single grain in a test tube, the seed weight, germination percentage and weight of the sprouts developing from these seeds were negatively correlated to the length of the feeding period.

EFFECTS OF LYGUS FEEDING ON CONIFER SEEDLINGS

J. K. Holopainen, Ecological Laboratory, Department of Environmental Hygiene, University of Kuopio, P.O.Box 6, SF-70211 Kuopio, Finland.

Damage to nursery grown conifer seedlings by *Lygus* bugs has been recently reported from Canada, Finland and USA. In Finland damage to Scots pine and Norway Spruce seedlings is predominantly caused by *Lygus rugulipennis* Popp. Hibernated adults of the bug cause damage to the seedlings from late May to late June, nymphs in July and early August and emerged adults in August. Apical meristem damage in cotyledon stage seedlings leads to a cessation of growth or the development of bushy, multiple-leadered seedlings. Feeding and oviposition may also cause split-stem lesions, which are potential infection sites for plant pathogens. In second and third-year pine seedlings *Lygus* feeding causes needle growth deformations and abnormal buds, which develop multiple shoots in the following spring. Multiple-leadered pine seedlings are not acceptable for forest plantation. The economic impact of *Lygus* feeding on conifer seedling production is discussed.

BURNING OF ALFALFA FOR LYGUS CONTROL (HEMIPTERA: MIRIDAE). B.D. Schaber*, T. Entz, Agriculture Canada Research Station, Lethbridge, Alberta, Canada T1J 4B1.

Burning of alfalfa (*Medicago sativa* (L.)) stubble can significantly reduce lygus populations in the year of the burn. The effects of the burn were dependent on the insect species and whether the alfalfa was burned before growth or at up to 20-25 cm of growth. *Lygus* spp.) populations were significantly decreased in plots burned before growth for the year of the burn, but were not significantly decreased when alfalfa was burned at 20-25 cm. Alfalfa plant bug (*Adelphocoris lineolatus* (Goeze)) populations were significantly decreased by both burn treatments during the year of the burn. There was no significant burn effect on five beneficial insect species in either year when alfalfa was burned before growth.

A long-term burn study (6 years) has shown that burning alfalfa stubble before growth appears in the spring significantly reduced lygus bug populations. Spring burning did not harm the alfalfa plant. Seed yields in burned fields were significantly higher than in unburned fields in the first year. In subsequent years, there was very little difference.

PROSPECTS FOR CULTURAL CONTROL OF LYGUS. M.J. Gaylor* and S.J. Fleischer, Department of Entomology, Auburn University, Alabama, USA 36849-5413.

In the southeastern U.S. *Lygus lineolaris* populations inhabit a predictable sequence of wild host plants. These hosts are abundant in the Highland Rim area of Alabama, where *L. lineolaris* is a key pest of cotton. However, a single genus of host, *Erigeron* spp., serves as the primary source of *L. lineolaris* dispersing to cotton. *Erigeron* is most abundant in disturbed habitats, including highway rights-of-way, where it is undesirable because of its tall growth. It may be possible to reduce *Erigeron* populations while increasing populations of *Verbena rigida* by modifying current roadside management regimes. Since *V. rigida* flowers over a longer time span than *Erigeron*, *V. rigida* may serve as a trap host for *L. lineolaris* during the time cotton is susceptible to injury.

PROSPECTS FOR BIOLOGICAL CONTROL OF LYGUS. W.A. Jones*, Biological Control of Insects Laboratory, USDA-ARS, 2000 East Allen Rd., Tucson, AZ 85719 and O.P. Young, Southern Field Crop Insect Management Laboratory, USDA-ARS, Stoneville, MS 38701.

Natural enemies are important mortality factors of *Lygus* spp. populations but the impact is highly variable. Their polyphagous feeding habits, combined with multivoltinism and high vagility complicates accurate assessment of both the natural controls and impact of any manipulative methods. However, several possibilities exist for enhancing natural enemy effectiveness. All stages are attacked by parasitoids and predators; pathogens attack nymphs and adults, especially in their hibernacula. Manipulation of natural enemies must be tailored to local host population dynamics and affected crops. Possibilities include conservation of natural enemies outside the crop environment, augmentation of stage specific parasitoids and predators, establishment of exotic parasitoids and genetic improvement of parasitoids. Current programs include augmentative releases of egg and nymph parasitoids and importation of exotic parasitoids for establishment.

PROSPECTS FOR CHEMICAL CONTROL OF LYGUS. G.L. Snodgrass, Southern Field Crop Insect Management Laboratory, USDA-ARS, Stoneville, MS 38701.

Control of *Lygus lineolaris* (Palisot de Beauvois) and *L. hesperus* Knight in the United States with organic insecticides has been practiced on several crops over the past 30 years. Resistance in both *Lygus* species to chlorinated hydrocarbons, organophosphates and carbamates has been documented. In this presentation, research conducted over a 7-year period on the chemical control of *L. lineolaris* in cotton is reported. Insecticides tested included several carbamates, organophosphates, and pyrethroids along with a formidine and an insect growth regulator. The effectiveness of each class of insecticide for the control of *L. lineolaris* is discussed.

PROSPECTS FOR INTEGRATED MANAGEMENT OF LYGUS. Thomas F. Leigh*, Department of Entomology, University of California, Davis, CA 93263 and Lawrence E. O'Keeffe, Department of Soil and Entomological Sciences, University of Idaho, Moscow, ID 83843, USA.

Lygus bug, *Lygus* spp., infestations are commonly under the suppressive influence of several entomophagous parasites and predators. Population numbers can be further reduced through agronomic practice modifications, alternate host management and selective use of insecticides. Management practices are particularly effective when consideration is given to phenology of both pests and the crops. Cultural modifications include selection of resistant cultivars, adjustments of plant population and planting date, and modification of fertility and irrigation practices. Alternate hosts may be managed to reduce the threat of *Lygus* infestation development and to enhance predator populations. Timely use of selected insecticides will reduce infestations of this pest group with minimum threat to natural enemies.

ON THE CLAWS OF ABDOMINAL LEGS OF SOME SATURNIID LARVAE. Kazumitsu OKUI, School of Liberal Arts & Science, Kitasato University, 1-15-1 Kitasato Sagami-hara-shi Kanagawa JAPAN 228.

The number and form of claws differ from species and their each instars. For example, 1st instar of *Antheraea yamamai*, have about 22 claws on the end of abdominal legs. But, in *Antheraea pernyi*, about 60 claws exist in double line (30+30). These number increase as instar go by.

Therefore number and arrangement of claws are considered one of the specific character of species. In this time, the author reports comparison of these claws about 3 Asian species and 1 New Zealand species.

LIGHT REQUIREMENT FOR GREEN PIGMENTATION OF *ANTHERAEA YAMAMAI* COCOONS. Y. Kato, Department of Biology, International Christian University, Mitaka, Tokyo 181, Japan.

The cocoons of the wild silkworm *A. yamamai* normally show green color, which is due to the presence of blue pigment and yellow one. Unlike the case of *Bombyx mori*, the larvae require light for green pigmentation of the silk glands, which function as cocoon materials making organs. When they are kept in a darkness, the glands lack blue component (of biliverdine type) and consequently produce a yellow cocoon. I report here (1) effective intensity of light and developmental stage at which larvae are sensitive to light, (2) haemolymph as a candidate of photoreceptive site, (3) possibility of hormonal involvement, and (4) the property of the pigments.

FINE STRUCTURES OF COCOON FILAMENT OF THE WILD SILKMOTHS AND THE FILAMENT FORMATION IN THEIR SILK GLANDS. H. Akai, Sericultural Experiment Station, Tsukuba, Ibaraki 305, Japan.

In wild silkmotths, their silk gland develops considerably during the final larval stage, and synthesizes the silk proteins as well as the case of *Bombyx mori*. Their silk proteins, fibroin and sericins, are synthesized in rough endoplasmic reticulum and transferred into Golgi complex, and secreted into the lumen pass through the other intracellular organelles in the gland cells. In *Antheraea yamamai*, the fibroin fiber secreted into the lumen makes numerous masses of fibroin fibers in the lumen. On the other hand, many large vacuoles are also formed in the spaces between the masses of fibroin fibers. During the spinning period these liquid silk is progressed forward, and concentrated by the dehydration in the middle silk gland. These vacuoles retain to the end in the process of the cocoon filament formation. Each cocoon filament contain more than 400 vacuoles ranging from 0.1 to 0.8 μ m in diameter in a section. The physiological characters of the cocoon filament are differ from that of *Bombyx mori*. Structural characters of cocoon filaments of the other wild silkmotths were also studied by electron microscope.

PROTEINS IN THE MALE ADULT REPRODUCTIVE ORGANS OF SILKWORMS. H. Shinbo¹⁾, M. Kiuchi¹⁾, H. Akai¹⁾ and G.M. Happ²⁾, 1); The Sericultural Experiment Station, Tsukuba, Ibaraki 305, Japan, 2); Department of Zoology, University of Vermont, Burlington, Vermont 05405, U.S.A.

The male reproductive organ proteins of seven silkworm species were compared with respect their immunocross-reactivity with the monoclonal antibody prepared against the proteins of tubular accessory gland of *Tenebrio molitor*. The species are: *Bombyx mori*, *Bombyx mandarina*, *Antheraea yamamai*, *Antheraea pernyi*, *Philosamia cynthia pryeri*, *Rhodinia fugax* and *Dictyoploca japonica*. Immunoblottings of male adult reproductive organ homogenates of the seven species probed with the monoclonal antibody revealed the existence of some strong cross-reactive polypeptides. It is noteworthy that reactive proteins were detected in the homogenates of ejaculatory ducts of the all species, although clear-cut differences were observed in the immunoblotting patterns of the seven species. In addition, the first traces of the reactive proteins in the homogenates of *B. mori* accessory gland were detected in 7-day pupae, and the strong accumulation of the proteins were seen in the homogenates from 9-day pupae, suggesting that the proteins are adult-specific.

PHYSIOLOGICAL STUDIES ON MOLTINISM AND VOLTINISM OF THE MULBERRY WILD SILKWORM, *BOMBYX MANDARINA*.

O. Ninaki*, Y. Taniguchi, K. Nagayasu and A. Watanabe, Department of Silkworm Breeding, Sericultural Experiment Station, Tsukuba, Ibaraki 305, Japan.

Mulberry wild silkworm, *Bombyx mandarina*, is a significant genetical source for silkworm (*B. mori*) breeding. Regarding the physiological characteristics, it has been reported that *B. mandarina* exhibits to be trimolting and bi- or trivoltine forms. As it was difficult to rear larvae in the laboratory, a new method of rearing was developed, and the moltinism and voltinism pattern of *B. mandarina* was studied.

Most of the larvae reared at the temperature of 24°C were tetramolters, and a small number of male larvae became trimolters at 27°C. When the larvae were reared at 30°C, a rate of approximately 58% and 8% of male and female trimolters was observed, respectively.

Concerning voltinism, about 80% of the moths which were derived from the larvae reared at 24°C oviposited with diapausing eggs, while, nondiapausing eggs were observed only in the egg batches from larvae reared at 30°C.

Accordingly, relatively low temperature such as 24°C in the larval stage results in the induction of trimolters and diapausing eggs, while the high temperature such as 30°C tend to induce trimolters and non diapausing eggs.

ARTIFICIAL HATCHING IN THE SILKMOTH, *ANTHERAEA YAMAMAI*: APPLICATION OF KK-42 AND KK-COMPOUNDS. K. Suzuki*, T. Fujisawa (Applied Entomology, Faculty of Agriculture, Iwate University, Morioka 020, Japan) and E. Kuwano (Department of Agricultural Chemistry, Kyushu University, Fukuoka 812, Japan).

By the application of KK-42 and KK-related chemicals to the eggs diapausing at pharate first instar of the silkmoth, we have been successful to break (or inhibit) that diapause. This finding would be useful to the development of the method of artificial hatching. An appropriate treatment for the diapause breakdown and hatching was the consequence as described below: The eggs 10-day old were chilled at 2 or 5 °C for 2 - 10 days and subsequently being applied by 20 μ g of KK-42 per egg, respectively. As a result, cumulative hatching was 90 % in 5.7 $\pm$ 1.1 days after the incubation. KK-80 also showed about the same effects. In addition, the dipping of 50 eggs into KK-42 solution (0.5 g/50 ml of acetone) induced the hatchability of 70 %. These results suggests the possibility of a mass method of artificial hatching in the silkmoth.

NUCLEOLUS ORGANIZERS IN THE WILD SILKWORM, *BOMBYX MANDARINA* AND THE DOMESTICATED SILKWORM, *B. MORI*. H. Maekawa*, N. Takada, N. Miyajima, H. Fujiwara, T. Ogura, M. Kobayashi^a and O. Ninaki^b, Dept. of Tech., NIH, Tokyo 141, ^aUniv. of Tokyo, Tokyo 113, ^bThe Seri. Exp. Station, Ibaraki 305, Japan

Two types (R^{a1} and R^{a2}) of nucleolus organizers were identified in the genome of *B. mandarina* (Japan) which occurs in Japan. Genetical analysis of a hybrid with *B. mori* suggests that the loci of both nucleolus organizers are allelic and correspond to the R^o locus of *B. mori*. These nucleolus organizers were segregated and inherited by the progenies based Mendel laws. The majority of the R^{a1} rDNA units had a 10.6kb length and when compared with the same size unit of the R^o ones, there were differences at two restriction enzyme sites. The 15.1kb unit observed in the R^{a2} locus was the same as the unit with the type II intron of R^o . The four major components of the R^{a2} rDNA, with lengths of 10.6, 15.1, 15.7 and 20.8kb were also found in the R^o locus, and thus the R^{a2} and R^o loci were considered to be closely related. In the case of *B. mandarina* (Japan), the respective distinct 10.6kb units which are functional, were observed in the allelic loci of R^{a1} and R^{a2} . Therefore in this paper the possibility of introducing the chromosomes of the interspecies in the genus *Bombyx* was considered.

DYEING OF NON-MULBERRY SILKS BY THE GIPS DYEING METHOD.

H. Kato, Department of Filature and Silk processing, Sericultural Experiment Station, Tsukuba, Ibaraki 305, Japan

In general, non-mulberry silks are poor in exhaustion of dyes, deep shade dyeing and color fastness compared with domestic silk, wool and the like. I detected Gips dyeing method for fibers that, even in a neutral bath dyeing process which is excellent in leveling property and does not cause dyeing specks, produces a degree of exhaustion which is higher than that obtained with an acid bath dyeing process and which is suitable for deep shade dyeing. The process for the Gips dyeing fibers is characterized by the use of a dye liquor containing Calcium sulfate, calcined (Gips) in amount of 1 - 2 % OWF (% by weight in relation of fibers). In all of cases of the examples for non-mulberry silks wherein Gips was added to the dye liquors, the degree of exhaustion and the surface dyeing concentration were remarkably improved in respect of the direct dye, acid dye.

SAMIA CYNTHIA DRURY (LEPIDOPTERA, ATTACIDAE): THE INFLUENCE OF SEASONAL STATE OF AILANTHUS LEAVES ON GROWTH AND DEVELOPMENT. B. Mauchamp, Laboratoire de Phytopharmacie, INRA, 78000 Versailles, France.

Samia cynthia is a wild silkworm living on ailanthus trees in the streets of Paris. During the winter season we can collect diapausing pupae; we keep them in cold conditions until appearance of leaves. In laboratory conditions, it is possible to obtain several generations, mainly if we rear the larvae on artificial diet. However, according to the quality of the diet the development can be modified. Artificial diet contains powder of leaves. We compared the growth and development of larvae reared on fresh leaves or on artificial diet. Larvae reared on young leaves or on diet containing leaf powder obtained from young leaves have development similar to this one of control (larvae living in ailanthus trees). If old foliage or diet with powder from old foliage is given growth and development are modified. Effects are similar to the effects of JH antagonists. We attempt to detect in old foliage some chemical being involved in this activity; at the insect level we attempt to determine what target could be affected. The influence of the food quality will be discussed to explain how aging may influence insect population.

ENVIRONMENTAL CONDITIONS SUITABLE FOR GROWTH OF THE JAPANESE OAK SILKWORM, *ANTHRAEA YAMAMAI* (LEPIDOPTERA : SATURNIIDAE).

S. Kuribayashi, Department of Sericulture, Sericultural Experiment Station, Tsukuba, Ibaraki, 305 JAPAN.

The environmental conditions suitable for indoor rearing *A. yamamai* was clarified as follows: The optimal temperature for rearing is 29°C in the 1st to 2nd instars, 27°C in the 3rd instar, and 25°C in the 4th and 5th instars. The optimal humidity is 80% in the 1st instar that is lowered by about 5% as an instar advances to 60% in the 5th instar. The photoperiodism is favorable with a cycle of 10 to 12 hr in the light and 12 to 14 hr in the dark. Air current, that is the most important in the grown and cocooning stages is ideal with 0.1 to 0.2m per second. It is desirable to supply water by installing drinking water pool or by spraying water to food leaves in the rearing place, at the advanced instar. The area of a rearing bed required in case of box rearing was about 0.03m² per 100 larvae in the 1st instar and it increased up to about 0.7m² in the 5th instar. The larvae grown are reared on the net held at a half way up from the bottom of the rearing box. As feces and diseased larvae fall down on the bottom of the box, larvae are always kept under a sanitary situation, that makes the larval density in rearing improved. Disinfection of rearing room, tools and body surface of larvae should be practiced. As insects inhabiting on food plant often cause disease of *A. yamamai*, leaves showing insect damage or with insect corpses should not be used as food.

RELATIONSHIP BETWEEN THE ACTIVITIES OF INDUCIBLE ANTIBACTERIAL SUBSTANCES AND RESISTANCE TO APNPV INFECTION OF CHINESE OAK SILKWORM, *ANTHRAEA PERNYI*. C.F. Zhang*, J. Ding and C.Z. Lu. Silkworm Research Institute of Liaoning Province, Fengcheng, Liao Ning Province, China.

Diapausing pupae of *Antheraea pernyi* were found to produce a series of inducible antibacterial substances in their hemolymph by injection of certain dead or viable bacteria. The antibacterial substances could kill and lyse a variety of Gram-positive and Gram-negative bacteria. The variation of inducible antibacterial activity of the diapausing pupae from 29 races, which belong to bivoltine race and univoltine race, was compared and significant differences were observed. The investigations of relation between the inducible antibacterial activity and the resistance to ApNPV infection were made by half-batch determination method. The preliminary results showed that the inducible antibacterial activity was higher in the pupa stage, the resistance to ApNPV was stronger in its younger larva stage. This seems to indicate that the humoral immunity of *A. pernyi* is related to its resistance to ApNPV infection.

CHINESE OAK SILKWORM, *ANTHRAEA PERNYI*, CULTURE IN CHINA. Z.S. Wu, Department of Agriculture and Animal Husbandry of Liaoning Province, No.2, Taiyuan Street, Shenyang, Liaoning Prov. China.

The sericulture of Chinese Oak Silkworm, *Antheraea pernyi*, has a long history of over 2000 years in China. Since the Chinese oak silkworm is rearing outdoor, it's seriously affected by biological and unbiological factors. So, the research on sericulture techniques were strengthened and great progress was made. On the aspect of rearing technique, a Protective-Rearing method for young silkworm was put into practice for preventing the young larvae from heavy damage of low temperature, and the technique of laying eggs on the paper as well as the disinfection of egg surface was also improved. For the control of the pests and the diseases, the mechanism and the regularity of occurrence of main oak silkworm disease and the pests was basically clear and some effective control methods were invented. The investigations of main species of oak tree and its natural flora were made and a suitable cultivation method for sericulture was carried out. For the egg reproduction of Chinese oak silkworm, a more complete system was established. All of these new techniques play an important role in development of Chinese oak silkworm in China.

CLIMATE AND ACRIDID BIOGEOGRAPHY AS CONCOMITANT FACTORS IN THE SPECIATION OF ORTHOPTERAN MERMITHID NEMATODES IN AUSTRALIA. G.L. Baker, Biological and Chemical Research Institute, N.S.W. Department of Agriculture, P.M.B. 10, Rydalmere, N.S.W., 2116, Australia.

There is a high level of endemism exhibited by orthopteran mermithid nematodes in the Australasian region. This endemism is also reflected, at the generic level, by their acridid hosts.

In moist upland regions of the eastern seaboard, the dominance of a complex of brachypterous acridid species has favoured mermithid nematodes by providing relatively stable host populations. The stability, conferred by the spatial heterogeneity exhibited by non-migratory brachypterous species, is believed responsible for the extensive speciation of mermithid nematodes in the region.

Dimorphic preparasitic juveniles, considered to represent sibling species, are found in species in the genera Agamermis, Amphimermis and Hexamermis, indicating continuing active speciation in the region.

TRANSMISSION OF THE PINE WOOD NEMATODE, BURSAPHELENCHUS XYLOPHILUS (NEMATODA: APHELENCHOIDIDAE), BY THE ADULT JAPANESE PINE SAWYER, MONOCHAMUS ALTERNATUS (COLEOPTERA: CERAMBYCIDAE), AND THE EFFECT OF THE NEMATODE ON THE LONGEVITY OF THE ADULT SAWYER. K. Togashi, Ishikawa Forest Experiment Station, Tsurugi, Ishikawa 920-21, Japan.

It has been known that M. alternatus adult transmits the pine wood nematode, B. xylophilus, which causes the pine wilt.

Forty adult sawyers were raised on excised pine twigs. Thirty-three sawyers showed unimodal nematode-transmission curves and two showed L-shaped curves. The averaged transmission curves of the sawyers carrying more than 10,000, 1,000 to 9,999, and 100 to 999 nematodes had a peak of about 1,500, about 370, and 38 nematodes per 5 days, respectively, which appeared during a period from the 20th to 35th day after emergence of the sawyer. No peak was obvious in the transmission curve of the sawyers carrying less than 100 nematodes. The number of nematodes carried by the sawyer at emergence had no effect on its food consumption per unit time. The longevity of adult became shorter as the number of carried nematodes increased. The percentage of nematodes remaining within a dead sawyer tended to increase as the initial number of carried nematodes increased.

DISPERSION OF *TRICHOPLUSIA NI* IN GEOGRAPHICALLY SEPARATE PLANTINGS. J.T. Trumble*, Department of Entomology, University of California, Riverside, CA 92521; J.V. Edelson, Texas Agric. Expt. Station, Weslaco, TX 78596; R.N. Story, Louisiana State University, Baton Rouge, LA 70803.

One objective of this study was to determine if the distribution of *Trichoplusia ni* in cabbage varied with larval growth stage or between widely-separated locations. In general, C , I , I and Taylor's Power Law were in agreement that *T. ni* larval populations were only slightly aggregated. However, small larvae (1-2 instar) were substantially more aggregated than larger larvae, creating the need for separate sampling programs for each category. Combining data from larval groups which not only exhibited variable dispersions, but had potential differences in behavioral patterns or mortality factors and rates, would be unlikely to produce a valid estimate for a characteristic aggregation of a species. Although a trend of decreasing aggregation from California > Texas > Louisiana was evident in 1984, additional regions need to be assessed before definitive conclusions can be made regarding population resource utilization patterns. However, these data clearly show that developing a sampling plan for two or more geographically distinct regions based on a single dispersion value for *T. ni* would not always be valid.

ESTIMATING ABSOLUTE DENSITY OF *LIRIOMYZA* ON TOMATO. T.G. Zebisch, D.J. Schuster* and J.L. Stimac, University of Florida, GCREC, Bradenton, FL 34203.

Yellow sticky traps were used with field cages to develop absolute density estimates of *Liriomyza trifolii* (Burgess) adult females on staked tomatoes in Florida. Linear equations were developed describing the relationship between the number of females trapped inside the cages and the number of females trapped outside the cages using the unknown, native populations. Equations were also developed to describe the relationship between the number of females introduced per cage (following the removal of the native population) and the number of females subsequently trapped inside the cages. These equations can then be utilized to estimate absolute density of females per plant from the number of females trapped.

USING INFORMATION ON HABITAT TO HELP ASSESS ARTHROPOD DENSITIES. A. M. SHELTON, Department of Entomology, New York State Agricultural Experiment Station, Cornell University, Geneva, NY 14456.

Habitat can be viewed on many different levels: a region, a group of fields, an individual field, or an individual plant. If we are to assess an arthropod's density in any one of these levels of habitat, it is important that we examine the influence of habitat on the distribution of the arthropod. Using *Thrips tabaci* as an example, the influence of habitat is used to help understand the between-field, within-field, and within-plant distribution of arthropods.

ASSESSING PEST POPULATIONS: SAMPLING AND MONITORING IN EUROPEAN VEGETABLE CROPS. Jan Theunissen, Research Institute for Plant Protection, P. O. Box 9060, 6700 GW Wageningen, The Netherlands.

Various methods to estimate pest populations in commercial vegetable crops are reviewed. Constraints to the implementation of available methods are due to statistical problems in sampling methodology. New approaches are needed to develop sampling and monitoring methods which are both reliable and acceptable to growers.

THE VALUE OF ARTHROPOD DENSITY ESTIMATES USED IN DECISION MAKING: METHODOLOGY AND CASE HISTORIES. J. P. Nyrop, Department of Entomology, New York State Agricultural Experiment Station, Cornell University, Geneva, NY 14456.

Estimates of arthropod density are often used to help guide decisions on the need for pest control actions. However, the value of this sample information, from the perspective of least-cost pest control, is rarely determined. Decision theory provides one means whereby this value can be assessed. Methods are briefly presented for calculating the value of the sample information when fixed sample sizes are used to estimate arthropod densities. When sequential classification sampling plans are used, these methods are more concise and can readily be implemented using a spreadsheet on a microcomputer. Results from heuristic simulations are presented which show that the value of sample information used in pest control decision making declines as the economic threshold declines or the value of the crop increases, and as the cost of control declines and the effectiveness of a control action increases. These heuristic results are compared with the calculated value of sample information used to determine the need for control of Leek moth (*Acrolepiopsis assectella* Z.) infesting leeks in the Netherlands and the European corn borer (*Ostrinia nubilalis* Hubner) infesting processing sweet corn in New York, USA.

A COMPARISON OF SAMPLING METHODS FOR THE COLORADO POTATO BEETLE IN POTATOES. G.W. Zehnder*, Virginia Polytechnic Institute and State University, Painter, Virginia 23420, USA. D.M. Kolodny-Hirsch, Environmental Resource Associates, Baltimore, Maryland 21231, USA. J.J. Linduska, University of Maryland, Salisbury, Maryland 21801, USA.

Cluster samples of potato stems were compared with single stem samples for estimation of Colorado potato beetle (CPB) populations in commercial potato fields. In general, Relative Net Precision (RNP) values for single-stem samples of CPB larvae and adults were greater than RNP values calculated from cluster samples. CPB counts from the tops of potato plants could be used to estimate whole-plant populations of CPB. Spatial dispersion patterns of CPB larvae and adults were determined and used in development of sequential sampling plans.

INFLUENCE OF CROP AND ECONOMIC THRESHOLD ON SAMPLING METHODOLOGY FOR VEGETABLE PESTS. Marshall W. Johnson, Department of Entomology, University of Hawaii at Manoa, Honolulu, Hawaii, U.S.A. 96822

Crop sampling is essential to integrated pest management programs if control actions are to be timed based on economically significant pest densities. Polyphagous species such as *Liriomyza* leafminers (Diptera: Agromyzidae) and greenhouse whitefly, *Trialeurodes vaporariorum* (Westwood), require a multitude of sampling methodologies due to their many host crops and varying economic thresholds between crops. Varying economic thresholds influence the value of some sampling techniques (e.g., presence/absence sampling) due to insect distribution. Rarely is there a high correlation between two sampling techniques (e.g., leaf samples vs. sticky traps) with respect to population estimates of a given species. The benefits and problems associated with simple random sampling, stratified sampling, sequential sampling and presence/absence sampling will be discussed.

USE OF MULTI-STAGE AND PRESENCE-ABSENCE SAMPLING FOR ASSESSING DENSITIES OF THE GREENHOUSE WHITEFLY (*TRIALEURODES VAPORARIORUM* WESTWOOD) IN TOMATOES. E. Yano, Division of Entomology, National Institute of Agro-Environmental Sciences, Tsukuba, Ibaraki 305, Japan.

Three-stage and Presence-absence sampling methods were adopted for assessing densities of the greenhouse whitefly in tomatoes. Three levels of sampling units, i.e. a plant, a leaf and a leaflet were assumed in the three-stage sampling method. Based on the method by Kuno (1976), the estimates of mean density per leaflet, the variances and the necessary numbers of samples for all developmental stages were calculated. The feasibility of presence-absence sampling techniques for assessing adult densities was examined. In order to collect informations of adult distribution between plants, release experiments of adults were conducted in a glasshouse. In most cases, the adult distributions stabilized as slightly aggregated distributions in 8-12 days. Several models were applied to describe the relation between the mean density per plant and the proportion of plants infested. The variance of the estimate and the necessary number of samples were calculated. Sequential sampling techniques were also applied to determine whether the density exceeded the critical density or not.

Production Economics In Worldwide Animal Commodities Subject To Disease Transmission

ECONOMICS OF LIVESTOCK PRODUCTION IN AREAS OF NORTH AMERICA INFESTED WITH AMBLIOMMA TICKS. D.R. Barnard*, USDA, Poteau, Oklahoma U.S.A., R.T. Ervin, Texas Tech Univ., Lubbock, Texas U.S.A., F.M. Epplin, Oklahoma State Univ., Stillwater, Oklahoma U.S.A., R.O. Drummond, USDA, Kerrville, Texas U.S.A., and J.A. Hair, Oklahoma State Univ., Stillwater, Oklahoma U.S.A.

Production loss in nursing Bos taurus beef cattle is a function of the number of feeding female Amblyomma americanum. The estimated injury threshold is 15 feeding female ticks per calf. Using a three part model comprising a damage function, product value, and treatment costs, the economic threshold for A. americanum ranged from 26 to 38 feeding female ticks per calf depending on the acaricide used. In stocker cattle, A. americanum significantly reduced liveweight gain in B. taurus. However, B. taurus x B. indicus cattle supported fewer ticks, and the rate of liveweight gain was not altered significantly. An average of 40 feeding female A. americanum reduced liveweight gain equivalent to ca. \$40 US per animal for B. taurus stocker cattle in 1986. Use of alternate breeding systems has been proposed as a management strategy for cow-calf producers with tick-infested pastures. Under the assumed differences, the proposed strategy to use B. indicus crossbred cattle on tick-infested pastures is economically sound in most cases.

PARASITIC ACARINES CAUSING ECONOMIC LOSS IN THE AMERICAS VS. ACARICIDE PRODUCTS AND SYSTEMS. J.L. Nuñez, Technical Department, Coopers Argentina and Parasitology Department, Veterinary School, University of Buenos Aires, Buenos Aires, Argentina.

In the Americas cattle, sheep and pigs are generally infected by acarine ectoparasites, of which the most important are ticks and scab mites. Ticks have a great impact on the production of Central America and the two northern thirds of South America, whereas scab mites are predominant in the south of the United States and most of Argentina. Figures representing the economic loss caused by acarine ectoparasites are presented. A brief review of the control measures is given and emphasis is laid on the new studies made with the Pour-On system. Finally, to stress the importance of the environment in the interaction host-parasite-environment, large-scale trials and campaigns carried out with Boophilus microplus as well as psoroptic scab are discussed in detail.

THE ECONOMICS OF TICK CONTROL IN AFRICA: PRODUCTION LOSSES CAUSED BY RHIPICEPHALUS APPENDICULATUS AND AMBLIOMMA HEBRAEUM. R.A.I. Norval*, ILRAD, Box 30709, Nairobi, Kenya and R.W. Sutherst, CSIRO Division of Entomology, P. Bag 3, Indooroopilly, Qld 4068, Australia.

The most common cattle ticks in Africa are Rhipicephalus spp., Amblyomma spp. and Boophilus spp.. To design cost-effective control strategies it is necessary to know the production losses caused by these ticks (assuming that cattle are immune to tick-borne diseases). Losses in growth and milk production caused by Boophilus spp. had been determined in Australia and the USA but similar information was not available for African Rhipicephalus and Amblyomma spp.. Investigations on the effects of these ticks on cattle were therefore carried out in Zimbabwe (1983-1988).

The effects of Rhipicephalus appendiculatus on growth and milk production were determined in indigenous Sanga and exotic Bos taurus cattle in a cool highland area; similar studies on the effects of Amblyomma hebraeum on Sanga cattle were carried out in a hot lowland area. Adults of both species caused significant losses; these were higher in the more tick-susceptible B. taurus animals.

THE RELATIONS BETWEEN CATTLE RESISTANCE TO AFRICAN TICKS AND FOOD PRODUCTION. Y. Rechav, Department of Biology, Medical University of Southern Africa, Medunsa, 0204, Republic of South Africa.

It is known that various breeds of African cattle acquired resistance to local ticks. The number of ticks carried by resistant cattle is lower than that which feed on non-resistant hosts. Weights of ticks follows the same pattern. It was also found that gamma globulin levels correlate well with both parameters mentioned above.

Experiments conducted on various laboratory animals indicated that an increased globulin level apparently serves as an indicator of host resistance. Weight loss of livestock is affected by the numbers of feeding ticks.

The effects of the tick population density, cost of tick control, and the advantages of tick resistant cattle on food production are discussed.

STUDIES ON THE ECONOMIC IMPACT OF CATTLE TICK CONTROL IN CENTRAL AFRICA. R.G. Pegram, H.G.B. Chizyuka, E.T. Mwase & Z. Tekle. FAO/DVTCS "Economics of Tick Control" project, Box 30563, LUSAKA, Zambia.

Increasing costs of tick control have led to the necessity for a complete re-assessment of its economic impact. Unfortunately, however, perceptions of the fundamental scientific approach to studies on production economics are equivocal. Some researchers advocate a 'systems approach' in which all production traits and their interactions are monitored simultaneously, whilst others profess that studies must produce specific data on selectively identified components in the system.

In studies being carried out in Zambia the former approach has been used. Moderate to large infestations of Amblyomma variegatum have been shown to cause significant depressions in liveweight gain. Preliminary analysis of recent data indicate that tick infestations decrease annual herd productivity by 20-30% (output of milk/cow and weight of weaner calf/cow). It is doubtful, however, that intensive tick control is economically justified in indigenous livestock systems in the univoltine environment of Central Africa.

INSECT REARING MANAGEMENT: AN OPERATING SYSTEM FOR REARING FACILITIES. Pritam Singh, Entomology Division, Department of Scientific & Industrial Research, Private Bag, Auckland, New Zealand.

In spite of the rapid advances in insect rearing within the last 20 years, its management has not been formalised into a universally applicable concept. Insect Rearing Management (IRM) is a scientific programme for multiple-species rearing facilities offering consistent supply of various species at all life stages, meeting precise requirement within a specified time frame. It is based on sound business management principles. By integration of colonisation, the rearing facility, research and development, and available resources one is enabled to achieve efficiencies in the rearing system, and economically produce insects of high quality.

Insect Rearing Management has been tested over a number of years. The general principles involved in its development will be discussed.

STUDIES ON THE NUTRITION AND DIGESTION OF ENTOMOPHAGOUS INSECTS LEADING TO THE DEVELOPMENT OF ARTIFICIAL DIETS. I.G.Yazlovetsky, Laboratory of Insect Biochemistry and Physiology, All-Union Institute of Biological Control, Prospect Mira 58, Kishinev 277060, USSR.

Ten recent years our lab carries out investigations on larvae nutrition and digestion peculiarities of insect predators (*Chrysopa carnea* Steph., *Podisus maculiventris* Say, *Perillus bioculatus* Fabr.) and parasites (*Trichogramma evanescens* Westw., *Bracon hebetor* Say). We study the composition of proteins, amino acids, lipids, carbohydrates and nucleic acids contained in different preys and hosts of the entomophages mentioned, composition and properties of the main digestive enzymes. While preparing and optimizing artificial diets recipes we take into account results of preliminary evaluation of hydrolysis grade and rate of their different protein, lipid and carbohydrate components of vegetative and microbiological origin by corresponding digestive enzymes of entomophagous larvae. On this basis we develop common strategy of creating artificial nutritional diets for insect predators and parasites.

MANIPULATION OF DIAPAUSE FOR STOCKPILING INSECTS USED IN BIOLOGICAL AND AUTOCIDAL CONTROL PROGRAMS. R.A. Bell, Insect Reproduction Laboratory, ARS-USDA, Beltsville, MD 20705

Many research or operational pest management programs involved in mass rearing and augmentative or inundative release of beneficial or sterilized insects could benefit by a capability to produce and stockpile such insects in a diapause condition on a year-round basis. Such a strategy requires, that the species must possess a diapause within its life cycle which can be induced, maintained and abruptly terminated in a practical manner in the laboratory. Development and use of such a capability could greatly increase the number of insects available for release and maximize the use of available rearing facilities. Recent research suggests that the required technology may already be available for implementation in the case of some insect species. For most species, especially beneficial insects, required knowledge is lacking. By an appropriate combination of environmental conditions, diapause may be induced and maintained up to a year or more in many insect species. Examples of practical methods that have been reported for rapid termination of diapause include exposure to high temperature and immersion in water or organic solvents. Hormones and genetic techniques may be used to manipulate diapause in the future.

THE EFFECT OF THE HOST PLANT ON THE BIOLOGY OF INSECTS AND THEIR NATURAL ENEMIES. M.J. Berlinger, Entomology Lab., Agricultural Research Organization, Gilat Regional Exp. Sta., Mobile Post Negev 85-280, Israel.

The performance of insects is affected by their food. While feeding, they are confronted with various plant external (e.g. hairiness) and internal (secondary plant substances) components, which have a tremendous impact on both the phytophages and their natural enemies. These plant features may cause death by toxicants; alter the normal development (molting, pupating) by interfering with the endocrine system; cause wing formation (in aptera aphids); change the duration of development stages and of the adult life span; alter the sex ratio, and the feeding behavior (stimulating or deterring); inhibit the production of the sex pheromone; synchronize the insect's seasonal cycle (inducing diapause); cause resistance to pesticides and to predators; and affect the searching capacity, and attractance (by kairomones and extrafloral nectaries) of parasitoids and predators.

SEASONAL AND NUTRITIONAL INFLUENCES ON THE TOXICOLOGICAL RESPONSE OF THE FIRST INSTAR LARVAE OF *SPODOPTERA LITTORALIS* (BOISDUVAL) IN A MASS REARING CULTURE. V. Flueck*, F. Bourgeois and P. Stoecklin, CIBA-GEIGY Limited, Agricultural Division, Basle, Switzerland.

A comparative study was made of two strains of *Spodoptera littoralis* Boisd. (Lepidoptera, Noctuidae) with particular reference to their developmental biology and their toxicological behaviour. Each strain had been bred over a period of years, one (D strain) on artificial diet only and the other (P strain) on plants only. Insects of the D strain that had been changed to a natural diet of plants only (DP strain) were also included in the study.

The D strain produced heavier pupae of more consistent size and had a shorter developmental cycle than the other two strains. The DP strain produced the lowest number of adult insects.

Finally the sensitivity of the three strains to three insecticides with different mechanisms of action was examined using freshly hatched larvae. A simple method (fitness ramp) was used to select larvae of a consistent standard. The D strain showed slight seasonal variations in sensitivity.

MULTIPLE INSECT SPECIES REARING IN SUPPORT OF RESEARCH. E. G. King and G. G. Hartley, USDA-ARS, Southern Field Crop Insect Management Laboratory, P. O. Box 346, Stoneville, Mississippi, USA 38776.

The capability to consistently rear large numbers of insects has necessarily often preceded pioneering efforts in genetic control, biological control, and other areas of entomological research. A continuous and consistent supply of insects of known quality accelerates and facilitates research on host-plant resistance and chemical control. So, fundamental research at the disciplinary level and plant-protection research on suppression or control strategies are served by insect rearing. The Southern Field Crop Insect Management Laboratory (SFCIML) has developed one of the best multiple insect species rearing programs in the world in support of research. About 12 insect species, pests, and natural enemies have been large-scale reared by the SFCIML, and eight species are presently being reared. In 1986, over 100 researchers from 22 states and three countries received 194 million life stages of nine species of insects from the SFCIML. The strategic location of a few facilities, designed specifically to rear multiple insect species, in the USA as well as other countries would assure the availability of a creditable supply of insects for conduct of research at a cost far less than is presently being required for maintenance of numerous small insect colonies at many locations.

QUALITY CONTROL IN INSECT MASS PRODUCTION: A REVIEW OF METHODS AND EQUIPMENT. N. C. Leppla, Insect Attractants, Behavior, and Basic Biology Research Laboratory, Agric. Res. Serv., U.S. Dept. Agric., Gainesville, FL USA 32604.

Insect colonization must be accomplished relative to the purpose, specifications and capability for rearing a species. Only after these conditions are clearly defined can specimens be collected, established in insectaries, and maintained appropriately. Quality control in insect mass production therefore constitutes strain maintenance within the colonization system, including the monitoring of rearing practices, processes, and products relative to established specifications. To facilitate this monitoring, a wide variety of behavioral and physiological measurements have been modified and incorporated into batteries of tests designed to predict the capabilities of mass produced insects to perform as autocidal control agents in the field. Global programs that utilize this technology are directed at such well-known pests as the Mediterranean fruit fly, screwworm, bollweevil, tsetse fly, and *Heliothis* complex. This paper is an indepth review of the state-of-the-art in monitoring the quality of mass produced insects.

INSECT REARING IN SUPPORT OF CLASSICAL BIOLOGICAL CONTROL.

R.F. Moore*, F. Gruber, W. A. Jones, and H. Hoyer. European Parasite Laboratory, USDA-ARS, American Embassy, Agriculture, APO, New-York, NY 09777.

A short slide presentation of the permanent facilities of the European Parasite Laboratory will be given.

Three illustrations of insect rearing in classical biocontrol will be discussed. *Crioceris asparagi* (L.) and its parasite *Lemophagus crioceritor* Aubert approach the ideal collection of a parasite because genetically diverse parasite can be collected from the host feeding on its natural food. *Trissolcus basalis* (Wollaston), an egg parasite of *Nezara viridula* can be collected from parasitized egg masses and the number increased but all individual from an egg mass may be limited. IPM programs use parasites in inundative, seasonal releases; thus, the parasites are the product of large scale and extended rearing. The effects of this rearing on selection and genetic diversity of the parasite will be discussed.

PROBLEMS WITH ENTOMOPATHOGENS IN INSECT REARING, G.G. Soares, Mycogen Corporation, 5451 Oberlin Drive, San Diego, CA, 92121, USA.

The accidental introduction of an entomopathogen into an insect colony can have devastating consequences leading to loss of the colony either through outright mortality or unacceptable effects that diminish insect quality and consistency. For this reason, entomopathogens are of primary concern to those involved in insect rearing.

The use of an artificial diet, when available, is crucial in minimizing contamination of colonies with pathogens by eliminating host plant material, which can be a major source of contamination. Likewise, good organization and sanitation within the insectary, proper air handling, use of HEPA filtration, sterilization of glassware and proper disinfection of cages, plasticware, glassware and surfaces are also critical in avoiding problems with entomopathogens.

These and other insectary strategies for minimizing disease problems are discussed in the context of those different types of pathogens, hosts and rearing methods with specific examples given.

AUTOMATIC MASS-PRODUCTION SYSTEM AND QUALITY CONTROL TECHNIQUE OF FRUIT FLIES: CASE OF THE MELON FLY, *DACUS CUCURBITAE* COQUILLETT(DIPTERA: TEPHRITIDAE), H. Nakamori*, H. Kakinohana and M. Yamagishi, Fruit Flies Laboratory, Okinawa Prefectural Agricultural Experiment Station, Sakiyama-cho, Naha 903, Japan.

The first fundamental studies on the tropical fruit flies mass-rearing used artificial diet were commenced in Hawaii about 1950. Establishment of mass-production method to produce several million pupae per week brought the first successful test of Sterile Insect Technique(SIT) in Mariana Islands. Furthermore, in 1970's, mass-production capacity was scaled up with expansion of the target area for eradicating the *Ceratitis capitata* in Costa Rica and Mexico. In Japan, mass-production of the melon fly started to eradicate it from Kume Is. using SIT. The Kume project was achieved successfully by 1977. In 1980, a large scale project aiming at eradicating the melon fly in the whole area of Okinawa was started. In the course of this project, a large scale of new mass-production facility was constructed. There, 200 million flies per week have been producing since 1987. In this facility, automatic rearing system were adopted for larval rearing, pupation, shifting and irradiation to decrease production cost. In this presentation, overview of past and current status in the fruit flies mass-production and the quality control method will be introduced.

HISTORY AND FUNCTIONS OF THE INSECT REARING GROUP.

R.E. Wheeler, Chevron Chemical Company, P.O. Box

4010. Richmond, Calif. 94804.

In the early 1960's, USDA scientists involved in insect rearing programs began to conduct workshops to improve art and science of insect rearing, and in 1975 established a news letter named "FRASS" as a communications vehicle among all scientists interested in insect rearing, world wide. Today the Insect Rearing Group is a strong volunteer group of over 500 members, dedicated and proactive in the advancement of insect rearing, through workshops, seminars, publications, and the FRASS newsletter. In recent years Publication and mailing costs have been subsidized by the American pesticide companies. A free subscription can be obtained by writing to this author.

MALIC ENZYME, PHOSPHOGLUCOTASE AND PHOSPHOGLUCOSE ISOMERASE ISOZYMES IN TRICHOGRAMMA. HUO SHAOTANG*, INSTITUTE OF PLANT PROTECTION, SHAANXI ACADEMY OF AGRICULTURAL SCIENCES, YANGLING, SHAANXI. PEOPLE'S REPUBLIC OF CHINA.

ME, PGM and PGI eletrophoretic banding patterns in 20 lab. coltures representing of *Trichogramma* were studied. Variations in PGM were found in *T. exiguum*, *T. marylandense*, *T. pretiosum*. PGI also showed variation in *T. exiguum*, *T. marylandense*, *T. minutum*, and *T. parkeri*. However, ME variations were found only in *T. pretiosum*. Based on progeny analyses, we concluded that ME is a tetramer in *Trichogramma* with fast and slow locus and alleles at a single locus and that both PGM and PGI have a single locus and each has four alleles. PGM is a monomer, but PGI is a dimer.

STUDIES ON *TRICHOGRAMMA BUESI* VOEGELE, A BIOCONTROL AGENT AGAINST *PIERIS RAPAE* (L.) IN EGYPT. M.S.T. Abbas, Plant Protection Research Institute, Nady El-Said Street, Dokki, Giza, Egypt.

T. buesi was reported for the first time by Voegelé (1985) who proposed the parasite as a new name for *T. brassicae*. Voegelé (1982) reported *T. brassicae* sp.n. as a parasite of eggs of *Mamestra brassicae* in France. In the present investigation *T. buesi* is recorded, for the first time, as an egg parasite of *P. rapae*. In addition this is the first study on such a species. Percent parasitism by *T. buesi* on eggs of *P. rapae* collected from cabbage fields ranged 0-31.5% in 1985 and 0 - 36.4% in 1986. The respective figures on eggs collected from turnip fields were 16-42% and 12.5-32.1%. At 27°C and 60-70% R.H. the number of progeny produced female was 98.5 adults during its life-time which lasted 10.7 days. the incubation period of the parasite's egg was 22 h, the larval and pupal stages lasted 3.2 and 4.6 days, respectively. Sex ratio in *T. buesi* was 1♂ : 1♀ in nature and 1♂ : 1.3♀ in the laboratory.

RELATIONSHIP BETWEEN HOST SELECTION AND HOST SUITABILITY IN THE EGG-PARASITE *TRICHOGRAMMA* (HYM.: TRICHOGRAMMATIDAE). G.A. Pak*, J.C. van Lenteren (1) and N. Hawlitzky (2). Dept. Entomology, Agricultural University, Wageningen, the Netherlands (1) and Zoology Laboratory, INRA, Versailles, France.

A candidate *Trichogramma* sp. to be selected for inundative biological control of Lepidoptera on cabbage should parasitize eggs of several host species. Intra- and interspecific variability in host selection for two major host species, *Mamestra brassicae* (Noctuidae) and *Pieris brassicae* (Pieridae) was found among laboratory strains of *Trichogramma*. Preference for eggs of *M. brassicae* over those of *P. brassicae* as a host by *Trichogramma* appears to be related to a difference in host suitability between the two species. A histological study on the process of parasite development in the two host species indicated that the nutritional quality of *Pieris* eggs is inferior to that of *Mamestra* eggs. *Trichogramma* females successfully kill *Pieris* embryos, but development of the immature parasites may be inhibited in the egg stage or as a larva. Inhibition of parasite development is influenced by environmental conditions, especially humidity. *Pieris* eggs appear to be less resistant to water loss than *Mamestra* eggs, probably due to differences in the structure and the thickness of the egg shell. Egg-shell structures have been investigated by means of scanning and transmission electron microscopy.

OVERWINTERING OF EGG PARASITE *TRICHOGRAMMA CACOECIAE* MARCHAL (HYMENOPTERA, TRICHOGRAMMATIDAE) AND ITS HOST ARCHIPS ROSANA (LEPIDOPTERA; TORTRICIDAE) IN VOJVODINA, YUGOSLAVIA. M. Grbić* and Ž. Srdić, Institute for Plant Protection, Agricultural University, Novi Sad, V. Vlahovića 2, Yugoslavia.

Overwintering of egg parasite *T. cacoeciae* and its host *A. rosana* has been followed using histological technique, preparations "in toto" and observations in the field.

In continental climatic condition of Vojvodina arrest in development of *T. cacoeciae* and *A. rosana* commence in June and lasts until late March-early April. The first eclosion of the adult parasites was registered on 30.03. and 26.03. and larval emergence of host on 9.04. and 7.04. respectively in 1985 and 1987 year.

Overwintering of parasite was in prepupal stage from July to December, when pupal stage occur and lasts until eclosion of adults. In two successive years 12.6% and 16.8% of total parasite population did not enter diapause. Stages of embrional development of *A. rosana* were determined in the field.

Diapause of host and parasite was possible to break in climatic chamber from late November. Our results indicate that diapausal development of host and parasite lasts until November when postdiapausal development starts.

POPULATION NUMBERS OF *SANDIA XAMI* (REAKIRT) (LEPIDOPTERA, LYCAENIDAE) IN THE PEDREGAL DE SAN ANGEL (MEXICO) IN RELATION TO A POSSIBLE REGULATING PARASITOID (*TRICHOGRAMMA PRETIOSUM* RILEY).

J. Soberón M. and B. Benrey B. Departamento de Ecología, Instituto de Biología, UNAM, México.

The number of eggs oviposited in a sample of the food plant of *S. xami* has been recorded weekly since October, 1983. The variation in the mean number of eggs per plant follows a seasonal pattern with relative low variation (from 0 to about .3 eggs per plant). Such low variation in numbers over more than four years suggest the presence of a regulating factor acting to prevent population outbreaks. Intraspecific competition is an unlikely candidate because the egg mortality caused by *T. pretiosum*, which results in most plants having seldom more than two or three larvae, not enough to deplete the resource. Examination of the weekly censuses show that parasitism by *T. pretiosum* may be density-dependent for at least an interval of the lower egg densities. Subsequent experiments supported this and lead us to propose a model of population regulation in which the density dependent factor regulate only at low densities, leading to a multiple-equilibria regime.

BIOCONTROL OF *OSTRINIA NUBILALIS* HB. ON CORN IN NORTHERN ITALY. S. Maini¹, C. Gattavecchia¹, G. Celli¹ and J. Voegelé², (1) Istituto di Entomologia "G. Grandi", Università, Via F. Re, 6, 40126 Bologna, Italy; (2) Station de Zoologie et de Lutte Biologique, INRA, Antibes, France.

Ostrinia nubilalis Hb. (Lepidoptera: Pyralidae) (ECB) has 2 generations yearly and always infests corn. The number of second-generation larvae can vary from 2 to 20 per plant, with 100% of plants infested (depending on year, hybrid, etc.). The ECB is naturally controlled by several predators and parasitoids, including *Trichogramma maidis* Pint.-Voeg. (Hymenoptera: Trichogrammatidae). Field trials using *T. maidis* in biocontrol tests were begun in 1982. ECB egg mass parasitization by *T. maidis* proved to be high: both in plots where it was released and in those where present naturally, although the rate was always higher in the former case, i.e. by about 40%. It is evident that to make biocontrol more effective, releases should be carried out over wider areas, i.e. at least 100 ha, or more isolated corn fields. For greater area coverage, ultra-light aircraft or other mechanical means should be employed in releases. *T. maidis* in cardboard capsules developed by INRA is well suited to this type of release. Crop losses due to ECB on tolerant hybrids, however, are not easily assessable. We have not yet been able to obtain clear-cut data on yield increases following *T. maidis* releases, but then neither have other Italian researchers working on insecticides. It is therefore our intention to continue research into biocontrol as an alternative to insecticides, which have been shown as harmful to wild *T. maidis* and other arthropods.

INUNDATIVE RELEASE OF THE EGG PARASITE TRICHOGRAMMA MAIDIS BY MEANS OF CARDBOARD CAPSULES FOR CONTROL OF OSTRINIA NUBILALIS. J. von der Heyde* 1), V. Harries 1), F. Bigler 2) and B. Crouzet 3), 1)Agricultural Experimental Station of BASF, 6703 Limburgerhof, W-Germany; 2)Swiss Federal Research Station of Agronomy, 8046 Zürich, Switzerland; 3)Groupe UNCAA, 75782 Paris, France.

The inundative release of the egg parasite Trichogramma spp. (Hymenoptera, Trichogrammatidae) in Europe has been successfully used for control of the European cornborer O. nubilalis Huebner (Lepidoptera, Pyralidae) on a larger field scale including first commercial applications. While in the past mainly cardboard frames have been used as a "carrier" for release of Trichogramma-parasites in the field, the presented system is based on wax-covered cardboard capsules containing the Trichogramma maidis Pintureau et Voegelé-parasitized host-eggs (Ephestia kuehniella Zell.).

With commencing moth-flight of O. nubilalis, 2 releases of each 200 capsules/ha (representing a total of 200 000 parasites/ha) at an approximately 8-day-interval resulted in successful reduction of O. nubilalis - infestation and increase of corn yield in Trichogramma-treated fields. When standard pyrethroid treatments have been used as a reference, in general the Trichogramma-activity on O. nubilalis-larvae achieved a comparable level of control.

THE RESEARCH ON RELEASING TRICHOGRAMMA DENDROLIMI FOR THE CONTROL OF ASIA CORN BORER, OSTRINIA FURNACALIS. SI QUIRONG*, PLANT PROTECTION STATION, MIYUN, BEIJING, LU QI* INSTITUTE OF AGRICULTURAL SCIENCES, YOUYI COUNTY, HEILONGJIANG PROVINCE, PEOPLE'S REPUBLIC OF CHINA.

Continuous inundative of a local strain of Trichogramma dendrolimi against asia corn borer, Ostrinia furnacalis have been made in Miyun county, suburb of Beijing and Youyi county, Heilongjiang Province since 1973. The 14 year results had showed that Trichogramma can be an effective agent as alternative to chemical control in the control of asia corn borer. In the released area, no pesticides have been used instead of releasing Trichogramma, the parasitism of Trichogramma was 82.6%-88.6% and the declining rate of pest population was 89.9%. As successive release of Trichogramma, natural enemies were protected from the toxicity of pesticides, the population of natural enemies increased from 16%-24% to 47%-55% compared with that before releasing Trichogramma. After 14 year release of Trichogramma, the amount of corn borers was 16.1 borers per 100 stems in release areas which was compared significant less than 193.7 borers per stems before release of Trichogramma in the same areas. Release of Trichogramma dendrolimi showed a successful suppression on asia corn borer.

RESEARCH ON TRICHOGRAMMA CHILONIS FOR THE CONTROL OF SOYBEAN POD BORER, LEGUMINORA GLYCEINIVORELLA. SONG MUQUAN*, BIOLOGICAL CONTROL STATION, LIUHE COUNTY, LIU JIAFAN*, OFFICE OF PEOPLE'S GOVERNMENT, TONGHUA CITY, JILIN PROVINCE, ZHANG FENG* AGRICULTURAL BUREAU, XIFENG COUNTY, LIAOLIN PROVINCE, PEOPLE'S REPUBLIC OF CHINA.

Investigation and field tests of Trichogramma spp. parasitizing the eggs of soybean pod borer, L. glycinivorella have been made since 1984. The results showed that T. chilonis was the dominant species of parasitoid attacking soybean pod borer in the field. The ability of T. chilonis to parasitize soybean pod borer eggs was much greater than T. dendrolimi, T. ostrinia and T. evanescens. T. chilonis is a principal factor for the effective suppression on soybean pod borer. T. chilonis have been released for the control of soybean pod borer since 1984 in 50,00 ha. The egg parasitism was 46.0%-65.2%, the rate of damaged pods was decreased 50%-80%.

THE INTEGRATED CONTROL OF VEGETABLE PEST MAINLY BY USING TRICHOGRAMMA. ZHOU YUNLING*, INSTITUTE OF PLANT PROTECTION, SHANXI ACADEMY OF AGRICULTURAL SCIENCES, TAIYUAN, SHANXI PROVINCE, PEOPLE'S REPUBLIC OF CHINA. The tests had been made in the vegetable field to apply improved items of Trichogramma as dominant technique, besides a series of agrotechnical measures such as adopting varieties resistant to plant diseases and pests, rotation and shift of vegetables with other crops, grafting and scientific and rational application of fertilizer. The results showed that vegetable diseases and pests were basically brought under control and we have have the goal of constructing good agro-ecological environment. During 1984-1987, such techniques were used over 10,000 ha. and resulted in an increase of yields of vegetable and a reduction of the cost of chemicalicides for the control pest and plant diseases. This technique have obtained evident social and ecological benefits.

THE STUDY ON PREVENTION AND CONTROL OF ADOXOPHYES ORANA FISHER VON ROSLERSTAMM BY TRICHOGRAMMA DENDROLIMI MASTSUMURA. FENG JIONGOU*, ZHONGYONG, INSTITUTE OF PLANT PROTECTION, SHANGDONG ACADEMY OF AGRICULTURAL SCIENCES, JINAN, SHANGDONG PROVINCE, PEOPLE'S REPUBLIC OF CHINA.

The demostrote test for prevention and control of Adoxophyes orana by Trichogramma dendrolimi on orchard area of Rusan and eihai county, Shangdong Province from had been made from 1984 to 1987. The apple orchard of release wasps is over 3333 ha. and the excellent effect has gained. According to the investigation, the release wasps 1.8 million per ha. in a successional times on the test land, the parasitized eggmass is only about 95% and the fruit bored is only 2-3%. The effect is better than the insecticide application. After the release wasps with laded ^{32}P , it was found that 78.26% parasitized eggmasses barred the ^{32}P , and the others were parasitized by natural wasps.

TRICHOGRAMMA SPP. PARASITIZING THE EGGS OF ASIAN CORN BORER OSTRINIA FURNACALIS AND ITS EFFICACY IN BEIJING SUBURBS. Zhang Zhili, Institute of Plant and Environmental Protection, Beijing Academy of Agricultural and Forestry Sciences, P.O. Box 2449-19, Beijing, China.

An investigation of Trichogramma spp. parasitizing the eggs of Asian corn borer Ostrinia furnacalis carried out in Beijing Suburbs since 1977. It was shown that I. ostrinae was the dominant species of parasitoid attacking corn borer eggs of all generations. The ability of I. ostrinae to parasitize corn borer eggs was much greater than other species of Trichogramma (e.g. I. dendrolimi, I. chilonis, I. evanescens and I. closterae). I. ostrinae is a key factor affecting populations of O. furnacalis in Beijing Suburbs. The results of laboratory and field experiments, using release of Trichogramma spp. showed that the control of corn borer with I. ostrinae was more effective than control using I. dendrolimi. The egg parasitism, bored holes per 100 stems and live borer larvae per 100 stems in treatments with I. ostrinae and I. dendrolimi were 94.09, 15.0, 3.2 and 52.17, 33.5, 20.5, respectively.

STUDIES ON THE APPLICATION OF *TRICHOGRAMMA*.
WANG CHENGLUNG, ACADEMY OF AGRICULTURAL
SCIENCES, JILIN PROVINCE, PEOPLE'S REPUBLIC OF
CHINA.

Trichogramma have already been used to control
pests of grain crop at beginning. The applied
range has been extended, not only corn borer,
but also control economic crop pests, for
example, it can control cabbage army worm of
sugar beet borer and sunflower moths.
It has too many years of history about
application research of *Trichogramma*, but
only recently used in production
practice. It has been considered a lot of
problems should be further solved, for
example: single host egg of *Trichogramma*
number, host eggs, disease on *Trichogramma*.
We believe that if we pay more attention to
the research of biology, ecology, behaviour
insect pathology science of *Trichogramma* and
raising application technique of
Trichogramma, we can expect that the research
for *Trichogramma* must be great developed.

CURRENT STATUS OF *in vitro* *Trichogramma pretiosum* REARING.
S. B. Vinson, W. C. Nettles, Jr., Wu Zhi-Xin, Xie Zhon-Neng,
Ken Irie and R. K. Morrison. Department of Entomology,
Texas A&M University and the Southern Crops Research
Laboratory, U.S.D.A., A.R.S., P.O. Box DG, College Station,
TX 77843.

The *in vitro* rearing of *Trichogramma pretiosum* has been
accomplished on several diets consisting of small amounts of
insect hemolymph, and various amounts of hen eggs, bovine
milk, salt and vitamin solutions. Several techniques have
been used to successfully rear these insects. The current
status of *in vitro* rearing, problems encountered, and
opportunities for the production of artificially reared
Trichogramma will be discussed.

ANTENNAL STRUCTURES IN *TRISSOLCUS BASALIS* (WOLL.) (HYM.:
SCELIONIDAE): MORPHOLOGY, HYPOTHETICAL FUNCTION AND POTEN-
TIAL FOR BIOTAXONOMY. F. Bin*, N. Isidoro, M. Solinas,
Agric. Entomology Inst., Perugia Univ., Borgo XX Giugno,
06100 Perugia, Italy, and S.B. Vinson, Dept. of Entomology,
Texas A & M, College Station, Texas 77843, USA.

Sensory and secretory structures are present on the
antennae of both sexes of this *Nezara viridula* egg parasitoid.
The external morphology (SEM) and internal ultra-
structure (TEM) of some of these structures have been studied
to understand their function. In particular a dorsal
gland is described in female club for the first time in
Proctotrupoidea Scelionidae.

The possible function of sensilla and glands in intra-
specific communication (sex- and host marking recognition)
and that of sensilla in interspecific relationships (host
selection process) is discussed.

These structures and their distribution provide new
characters-important for taxonomy and phylogeny-for Scelionidae
and Proctotrupoidea.

BIOLOGICAL CONTROL OF GRAPE MEALYBUG IN THE CAUCASUS. V.A. Yasnos h. Plant Protection Institute, Tbilisi, USSR.

Planococcus ficus (Sign.) (Hom.:Coccinea)—serious pest of grape, figs, some ornamental plants on Black Sea coast and Transcaucasian regions. Mealybug natural enemies complex consists of more than 20 native insects from which *Anagyrus pseudococci* (Girault) (Hym.:Encyrtidae) and some predatory coccinellids are more effective. Introduced predator *Cryptolaemus montrouzieri* Muls. is used for control of mealybug more 50 years but its effectiveness in the regions characterized by low humidity and high insolation is lower. For biological control optimization recently new bioagents were introduced from France: *Leptomastix dactylopii* (How.) (Hym.:Encyrtidae)—reintroduction; *Nephus reunioni* Fur. (Col.:Coccinellidae).

Biological control measures adopted against grape mealybug in different regions of Caucasus are discussed.

COMPARISON OF RELATIVE MAGNITUDES OF DEMOGRAPHIC VARIABILITY WITHIN AND AMONG POPULATIONS OF GRAPE PHYLLOXERA (HOMOPTERA: PHYLLOXERIDAE). D. Hawthorne*, T. J. Dennehy, and S. Via, Department of Entomology, New York State Agricultural Experiment Station, Cornell University, Geneva, New York, USA 14456, and Department of Entomology, Cornell University, Ithaca, New York, USA 14853.

Evolution of highly adapted genotypes (biotypes) of phylloxera is made possible by clonal variation in survivorship and fecundity on novel grape rootstocks. The purpose of this study was to evaluate the relative magnitude of demographic variability within and among geographically isolated populations of phylloxera collected from wild grapes. To accomplish this we estimated clonal variability in life history parameters on two host species. Experimental estimates of demographic variability of insects on new hosts may prove useful for predicting the durability of resistant germplasm.

THE NATURAL ENEMIES OF SCALE INSECTS IN TAIWAN. Tsong Hong Su*, Department of Entomology, National Chung Hsing University, Taichung, Taiwan, R.O.C.

A general survey of the natural enemies of scale insects is being conducted in Taiwan. The important predators of Pseudococcidae, Diaspididae, and Coccidae are listed. *Planococcus citri* (Risso): *Leptomastix dactylopii* Howard, *Pauridia peregrina* Timberlake (Hym. Eurytomidae). *Nipaecoccus vastator* (Mackell): *Anagyrus dactylopii* (Howard) (Hym. Encyrtidae). *Saccharicoccus sacchari* (Cockerell): *Anazyrus saccharicola* Timberlake (Hym. Encyrtidae). *Aspidiotus destructor* Signoret: *Aphytis chrysomphali* (Mercet) (Hym. Aphelinidae). *Chrysomphalus ficus* Ashmead: *Aphytis chrysomphali*, *Aphytis holoxanthus* DeBach (Hym. Aphelinidae). *Parlatoria zizyphus* (Lucas): *Aphytis proclia* (Walker) (Hym. Aphelinidae). *Coccus viridia* (Green): *Microterys speciosus* Ishii (Hym. Encyrtidae); *Aneristus ceroplaste* (Howard), *Coccophagus tibialis* Compere (Hym. Aphelinidae).

SPATIAL AND TEMPORAL DISTRIBUTION OF HOMOPTERAN APPLE PESTS IN AN UNSPRAYED ORCHARD IN WEST VIRGINIA, U.S.A. F.Kozár*, Plant Protection Institute, Hungarian Academy of Science, Budapest, Hungary, M.W.Brown and G.Lightner, USDA-ARS-Appalachian Fruit Research Station, Kearneysville, WV, U.S.A. 25430.

The spatial distribution of 5 Homopteran apple pests: *Parthenolecanium corni*, *Quadraspidiotus perniciosus*, *Eriosoma lanigerum*, *Dysaphis plantaginea*, *Aphis* spp., and predators *Aphidoletes* sp, *Coccinella septempunctata*, and spiders were examined in a 4-year-old, unsprayed, 75-tree orchard, with 5 cultivars, weekly, and biweekly in 1987 and 1988. Data analysis was with Chi-square, correlation, analysis of variance, and graphical techniques. The pattern of distribution among phytophagous species were generally not correlated. There were no consistent differences due to cultivars. Significant positive correlations between *Aphis* and *Aphidoletes* in June indicated that this predator was responsible for an early decline in *Aphis* populations. Later generations of *Aphis* and *E. lanigerum* were kept low by generalist predators, *C. septempunctata* in particular.

AFRICA-WIDE BIOLOGICAL CONTROL PROGRAMME: BACKGROUND, INTRODUCTION AND DISPERSAL OF PARASITIDS AND PREDATORS OF THE CASSAVA MEALYBUG, *PHENACOCCLUS MANIHOTI* MATILE-FERRERO (Homoptera: Pseudococcidae). H.R. Herren*, P. Neuenschwander and W.N.O. Hammond, International Institute of Tropical Agriculture, P.M.B. 5320, Ibadan, Nigeria.

The Africa-wide Biological Control Programme (ABCP) was set up at the International Institute of Tropical Agriculture (IITA), Ibadan, in 1980. Its goal is to assist, through research, training and implementation, African countries whose cassava crop is being devastated by two pests accidentally introduced from South America. Since 1981, the exotic parasitoid *Epidinocarsis lopezi* (De Santis) has been imported into Nigeria for the control of the cassava mealybug, *P. manihoti* along with two other species of parasitoids and five species of predators. They were multiplied in an insectary at IITA, and have been released since 1981 through the ABCP and its national programme network. By January 1988, a total of over 70 releases in 35 regions have been made in 15 African countries. The most successful natural enemy, *E. lopezi*, has already become established in 28 regions. It now occupies 1.5 million km² in 19 countries (in four instances *E. lopezi* crossed international borders) covering a range of ecological zones (Sudan Savannah, Guinea Savannah, Equatorial Rainforest, Highlands). Three other exotic natural enemies species have become established in several locations.

A BIOLOGICAL AND ECONOMICAL ANALYSIS OF THE IMPACT OF EXOTIC BIOLOGICAL CONTROL AGENTS ON THE CASSAVA MEALYBUG, *PHENACOCCLUS MANIHOTI* MATILE-FERRERO (Homoptera: Pseudococcidae). P. Neuenschwander*, W.N.O. Hammond, International Institute of Tropical Agriculture, P.M.B. 5320, Ibadan, Nigeria, and A.P. Gutierrez, Division of Biological Control, University of California, Berkeley, 1050 San Pablo Avenue, Albany, CA 94706, USA.

The effectiveness of the hymenopterous parasitoid *Epidinocarsis lopezi* (De Santis) in controlling the cassava mealybug (CM) *P. manihoti* was assessed using emergence samples. It is concluded that *E. lopezi* is responsible for (1) the declines observed in CM densities and damage symptoms and (2) the reduction of coccinellid abundance via competition for a common food source. It is also concluded that hyperparasitism does not stop *E. lopezi* from being an efficient parasitoid. The impact of CM on growth and tuber yield of cassava, and the influence of its biological control by *E. lopezi* were also investigated in surveys in Ghana and Côte d'Ivoire over an area of 180,000 km² of the savannah and forest ecosystems. Average yield reductions were 81.6% in fields with infestations of 100 CM per tip, or using a plant terminal damage scale, 97.8% yield loss was found compared with uninfested fields. The trends were all consistent with the hypothesis that the introduction of *E. lopezi* and its control of CM reduced substantially the yield losses in cassava. The length of time that *E. lopezi* had been present in an area was the most important factor influencing CM densities.

SOME COMPLEMENTARY STUDIES OF BIOLOGICAL CONTROL OF THE WHITE PEACH SCALE, *PSEUDAULACASPIS PENTAGONA* (TARGIONI-TOZZETTI) IN GUILAN PROVINCE, IRAN. A. Habibian* and H. Bayatassadi, Plant Pests and Diseases Research Laboratory of Guilan, P.O. Box 133, Anzali, Iran.

In 1972, the white peach scale, *Pseudaulacaspis pentagona*, appeared as a major pest on mulberry in Guilan Province, Iran. This scale has three generations annually – the first begins in early May, the second around July 10th, and the third in early September. It passes the winter as an adult female. Investigations of biological control by the endoparasite *Encarsia berlesesi* (Howard) (Aphelinidae) indicated that the rate of parasitism was around 30%. Temperatures of 0° and -2°C caused mortality on all stages of the parasite. The ectoparasite, *Aphytis* sp. (Aphelinidae) was also encountered and its rate of parasitism was recorded around 5%. Other natural enemies in this region were *Chilocorus bipustulatus* L. (Coccinellidae) and *Aspidiotiphagus citrinus* (Aphelinidae). However, both species are polyphagous.

THE EFFECTIVENESS OF SOME INDIGENOUS MATERIALS AS REPELLENTS OF *DIALEURODES PALLIDA* SINGH (HEMIPTERA: ALEYRODIDAE). Y.D. Pandey and M.L. Das, Department of Life Science, Tripura University, Agartala-799004, India.

The chewing of green leaves of *Piper betle* L. (Family: Piperaceae) is associated with ancient cultural and ritual life among populations of South Asian countries. *Dialeurodes pallida* Singh has, during the past several years, assumed status of a serious pest of betel vines. Its population remains above economic injury level during most part of the year. The local farmers resort to 20-30 sprayings per year of organo-synthetic insecticides which though effective pose serious health hazards. Application of fish-garlic mixture (1:1) diluted in water (1:5) proved highly effective as a repellent for a week. Extract of *Paederia foetida* (Family: Rubiaceae) also significantly repelled the adult population up to 5 days and its effectiveness extended up to 50 sq.cm. untreated foliage area. The natural plants showed higher repellent action as compared to the extract.

FIELD MONITORING FOR INSECTICIDE RESISTANCE OF *BEMISIA TABACI*. N. Prabhaker* and N. C. Toscano, Department of Entomology, University of California, Riverside, California, 92521, USA.

Chemical control is the primary method used to control the sweetpotato whitefly, *Bemisia tabaci*. However, control of *B. tabaci* is difficult due to the development of resistance to a number of insecticides. Resistance management should be an integral part of a control strategy that relies on multiple applications of chemicals. An effective method of monitoring resistance has been developed that permits resistance levels to be evaluated directly in the field using yellow sticky cards incorporated with insecticides. A series of dosages of two selected insecticides, cypermethrin and sulprofos, were sprayed on the yellow sticky cards to obtain concentration/mortality lines. By this technique, 19 locations in the Imperial Valley of California were monitored for resistance. The LC_{50} values of the field strains and the susceptible strain were used to calculate resistance ratios. Differences in resistance levels were observed among fields from the 19 locations. Results from this study encourage routine monitoring of resistance levels directly in the field.

POPULATION MANAGEMENT OF *THRIPS PALMI* KARNY ON FRUIT VEGETABLES IN GREENHOUSE. Akira KAWAI* (Kurume Branch, National Research Institute of Vegetables, Ornamental Plants and Tea, Kurume, Fukuoka 830, Japan) and Chikayoshi KITAMURA (Hokkaido National Agricultural Experiment Station, Sapporo, Hokkaido 004, Japan).

Thrips palmi KARNY is the most serious pest of fruit vegetables (Cucumber, Eggplant, Sweet pepper and so on) in Japan. The population model of *T. palmi* in greenhouse was made based on the population data. The effectiveness of various control methods was simulated using this model, and an effective control system was sought. The control threshold (CT) must be set as low as possible because of the low density effect, and the pursuit spraying method (insecticide is sprayed when the population exceeds CT level and several days after the spraying regardless of population density) is effective to reduce the frequency of spraying. However, it is difficult to control *T. palmi* using insecticides alone from the standpoint of safe use of agricultural chemicals. Prevention of greenhouse invasion, reduction of density on seedlings and mass trapping using sticky traps are other effective control methods. The integration of these methods and chemical control methods is the most effective control system.

SAMPLING PROCEDURES FOR WESTERN FLOWER THRIPS, *FRANKLINIELLA OCCIDENTALIS* (PERGADE) (THYSANOPTERA: THIRIPIDAE) AND ITS PREDATOR *AMBLYSEIUS CUCUMERIS* (OUDEMANS) (ACARINA: PHYTOSEIIDAE) IN GREENHOUSE CUCUMBERS. M.Y. Steiner, Alberta Environmental Centre, Vegreville, Alberta, Canada T0B 4L0.

Western flower thrips has been a major pest of greenhouse cucumbers in Alberta since 1983. An ongoing study is aimed at including this pest in an integrated control program, with a necessary requirement being the development of sampling procedures for western flower thrips and its predator, *Amblyseius cucumeris*, and the establishment of economic threshold levels. Studies to date indicate that middle strata leaves are better sampling units than upper or lower leaves, and that the distribution of both adult and larval thrips and *A. cucumeris* can be described by Taylor's power law, with aggregation coefficients of 1.31, 1.62 and 1.31 respectively. Using this relationship, correlations are demonstrated for comparing presence-absence sampling with actual population estimates obtained by both visual inspection and leaf washing. Damage to new fruit was poorly correlated with presence or numbers of western flower thrips on leaves. The difficulties in establishing economic threshold levels are discussed.

POPULATION TRENDS OF *MEGALUROTHRIPS USITATUS* (BAGNALL) (THYSANOPTERA: THIRIPIDAE) ON ADZUKI BEAN EXAMINED AND COMPARED BY FOUR SAMPLING METHODS. N.T. Chang, Department of Plant Protection, National Pingtung Institute of Agriculture, Pingtung, Taiwan, R.O.C.

During the winter growing season which from late of September to the early January of next year, adzuki bean (*Vigna angularis*) could be seriously attacked by *M. usitatus* at southern area of Taiwan. The field survey indicated that thrips population increase rapidly during 1st to 10th of December, i.e. 50 to 60 days after adzuki bean being planted. The highest larvae number occurred one week latter than the peak of adults. Three sampling methods (flowers collected, sticky traps, water traps) were examined and compared with the whole plant samples. Although there were no significantly different ($p=0.05$) in both time cost and relative variation among these three sampling methods, the sticky traps and water traps were the most precise methods basing on the relative net precision criterion.

DISINFESTATION OF FRESH ASPARAGUS WITH
CONTROLLED ATMOSPHERES. Alan Carpenter* and
R.E. Lill, Horticultural Research Centre,
Private Bag, Levin, New Zealand.

Controlled atmospheres offer a method of
controlling infestations of insects on export
produce that avoids the use of toxic fumigants.
Such disinfestation is slow acting but can be
effective if its use is fitted into existing
product handling systems. The main pests on
asparagus exported from New Zealand are thrips
and aphids. Concentrations of carbon dioxide
above 5% and oxygen levels as low as 2% provide
100% control of these insects in 10-14 days
without affecting asparagus quality and fitting
well with the 16-18 day shipping time to Japan
and the USA. Further manipulation of the
storage conditions may speed the process.

POSSIBILITIES FOR USING THE SPINED BUG (*PODISUS MACULIVENTRIS*) IN THE SYSTEM OF INTEGRATED PLANT PROTECTION AGAINST THE COLORADO BEETLE. Antonia V. Mateeva-Radeva, Higher Agricultural Institute, Department of Entomology, Mendeleevstreet 12, Plovdiv, 4000 032 23-21-12, Bulgaria.

The Colorado beetle, *Leptinotarsa decemlineata* Say, is economically the most important pest of potatoes and eggplants in Bulgaria. In connection with the reduction of chemical materials for its control, as well as to the conservation of natural environment, an investigation of the application of an integrated pest management system was undertaken. Emphasis was given to microbial preparations and bioagents. The possibility of using *Podisus maculiventris* in the control of the Colorado beetle was investigated. The technology was developed for its large scale production, as well as for the rates of its application in the field in relation to production and the type of crop. The results obtained are very promising for the effective use of *P. maculiventris* in the biological control of Colorado beetle in Bulgaria.

OBSERVATIONS ON THE EFFECT OF VARIOUS PREY SPECIES ON TWO PREDATORY FLOWERBUGS, *ANTHOCORIS NEMORUM* L. AND *ANTHOCORIS GALLARUM-ULMI* (DEG) (HETEROPTERA: ANTHOCORIDAE). E. F. DWUMFOUR, INST. OF PLANT PATHOLOGY & PLANT PROTECTION OF THE GEORG-AUGUST-UNIVERSITY GÖTTINGEN:

Nymphal mortality was much lower in the series of *Anthocoris nemorum* L. reared on their natural prey species, *Microlophium carnosum* Theo./Buckt., (11.9%) and *Tetraneura ulmi* (L.) (13.9%). A high percentage of nymphs held on the common spider mite died before imaginal eclosion. Significant higher numbers of immatures of the congener, *Anthocoris gallarum-ulmi* maintained on the green peach aphid and on the large nettle aphid reached adulthood. The black bean aphid, *Aphis fabae* Scopoli, was unsuitable for nymphal development. Instar duration as well as weight development differed significantly in individuals reared on the common spider mite from those fed other prey species.

For both *Anthocoris* species and in all dietary regimes weights of teneral adults varied between sexes. Development time for female individuals did not differ significantly from figures evaluated for male counterparts. Growth-Rate-Indices were, therefore, higher in females. Linearities (negative correlations) were established between development period and weights of adults.

BIOLOGY OF *NEUROCOLPUS LONGIROSTRIS* KNIGHT (HEMIPTERA: MIRIDAE) IN CENTRAL CALIFORNIA. R.E. Rice* and R.A. Jones, Department of Entomology, University of California, Davis, California 95616.

Neurocolpus longirostris is one of several Miridae that cause economic damage to commercial pistachios, *Pistacia vera*, in California. The primary native breeding host for *N. longirostris* is California buckeye, *Aesculus californica* (Spach) Nutt. (Hippocastanaceae) which grows in the Sierra Nevada and Coast Range foothills up to 1300 m. Adult *Neurocolpus* migrate from buckeye into pistachio orchards planted in foothill areas and develop endemic populations that must be controlled in early spring.

Eggs are laid in new growth twigs of pistachio or buckeye between buds and leaf petioles during May-July. Bugs reared on fresh *Aesculus* flower panicles at 23 ± 1.5°C in petri dishes completed nymphal development in 17.8 days; adults lived an average 27.4 days. Egg hatch in the field is closely synchronized with flowering and nut development in April-May.

Several egg parasites have been reared from *Neurocolpus*, including a species of *Chaetostricha* (Trichogrammatidae) and a species of *Erythmelus* (Mymaridae).

GEOSTATISTICAL DESCRIPTION OF THE SPATIAL DISTRIBUTION OF *LYGUS HESPERUS* IN LENTILS. Dennis J. Schotzko* and Larry E. O'Keeffe, Department of Plant, Soil and Entomological Sciences, University of Idaho, Moscow, Idaho 83843, USA.

The spatial distribution of *Lygus hesperus* Knight (Heteroptera: Miridae) in lentils was determined over two years at 5 locations using geostatistical methods. Geostatistics utilizes autocorrelation to determine the degree of association and dependence of temporally or spatially related data. Analysis revealed unique spatial distributions for both adults and nymphs, which varied as the growing season progressed and population densities changed. Immigrational adults were in clumped distributions. During the middle of the growing season adult distributions were found to be clumped at low densities, and uniform or random at higher densities. At the end of the growing season, newly emerged adults again exhibited a clumped distribution. Nymphs exhibited random to uniform distributional patterns until late in the growing season; as population densities increased, their spatial distribution became clumped. When compared to traditional methods of evaluating insect distributions, geostatistics produced similar variations in the distribution of this insect relative to densities and seasonal development. Geostatistics provide a more accurate method of defining and evaluating temporal and spatial dependence of data, and allow for the use of very accurate sampling procedures and generation of spatial maps of the insect populations.

CROP COMPENSATION FOR DAMAGE BY *LYGUS ELISUS* VAN DUZEE (HETEROPTERA: MIRIDAE) INFESTING OILSEED RAPE, *BRASSICA NAPUS* L. AND *BRASSICA CAMPESTRIS* L., IN ALBERTA, CANADA. R.A. Butts*, Alberta Environmental Centre, Vegreville, Alberta, Canada T0B 4L0, and R.J. Lamb, Agriculture Canada, Winnipeg, Manitoba, Canada R3T 2H9.

L. elisus adults were confined on reproductive structures of oilseed rape, *B. napus* and *B. campestris*. Significant bud and flower damage occurred on confined plants. However, the number of pods produced on plants confined in these stages was not significantly different from those produced on nonconfined plants. Plants compensated for bud and flower loss by activating buds that would otherwise have been aborted naturally. Confinement of seed pods produced a significant number of damaged seeds in 1984. There was partial compensation for this seed loss. However, the number of healthy seeds and weight per pod declined as damage increased. In 1986, confinements produced significant seed loss only in *B. napus*. However, damage to the pod coat and stem resulted in a significant reduction in seed weight per pod in both crop species. *Lygus* bugs are potentially serious pests of oilseed rape because significant damage may occur during the early pod stage. The phenology of *L. elisus* ensures that later instars and adults will be present on the crop at that time.

FEEDING TRANSMISSION OF A BACTERIAL PATHOGEN OF THE LEAF-HOPPER, *EUSCELIDIUS VARIEGATUS* (KIRSCHBAUM). Alexander H. Purcell, Department of Entomological Sciences, University of California, Berkeley, California 94720 U.S.A.

An unidentified, Gram-negative bacterium (BEV) that is transovarially transmitted by *E. variegatus* (J. Invert. Pathol. 48: 66) was transmitted to membrane-enclosed sterile solutions during feeding by this leafhopper. The BEV bacterium was cultured from over 50% of the solutions fed on by single BEV-infected leafhoppers in experiments where leafhopper mortality was low during an 18-24 hour feeding exposure. BEV was not often cultured (<10%) from the hemocoel of uninfected *E. variegatus* that had fed briefly on suspensions of BEV in feeding solutions but was cultured from over 60% of the leafhoppers exposed for 7 days to plants which had recently (<5 days) been fed on for 7 days by BEV-infected leafhoppers. BEV was detected in the hemolymph of *E. variegatus* beginning 3-4 weeks after the leafhoppers acquired BEV by feeding. However, plants exposed to BEV-infected *E. variegatus* and then kept free of leafhoppers for 2-4 months did not serve as sources for leafhopper acquisition of BEV. This suggests that BEV survives within or on plants for brief periods and that plants may serve as a conduit for the transmission of BEV from leafhopper to leafhopper.

ESTERASE AND ISOCITRATE DEHYDROGENASE ENZYMES IN *NEPHOTETTIX VIRESCENS* (DISTANT) (HOMOPTERA: CICADELLIDAE) POPULATIONS FROM INDIA, SRI LANKA AND THE PHILIPPINES. G.F. Rajendram, Department of Zoology, University of Jaffna, Sri Lanka.

Patterns of esterase and isocitrate dehydrogenase (IDH) activity were studied in *Nephotettix virescens* (Distant) populations from India, Sri Lanka and the Philippines, maintained in glass houses, on rice variety IN-1, at University College, Cardiff, United Kingdom. Adult insects of both sexes were analysed, using starch gel electrophoresis, and the gel stained for esterase and IDH enzymes.

Three zones of activity were observed in esterase in all three populations. India and Sri Lanka populations had esterase bands at relative mobilities of 1.0 (0.97, 0.94), 0.38 and 0.20 while the Philippines population had bands at 1.0 (0.97, 0.94), 0.29 and 0.12. Hence the Philippines population could be distinguished from India and Sri Lanka populations. Esterase-1 band appears to be sex-related since more intense in females.

Only one IDH band was seen at relative mobility of 1.0 in the males and 0.78 in the females in all three populations.

The results agree with previously reported divergence in the acoustical behaviour of *N. virescens* from Sri Lanka and the Philippines.

FACTORS INFLUENCING THE FEEDING BEHAVIOUR OF TWO AUCHENORRHYNCHAN RICE PESTS. P.M. Lösel* and L.J. Goodman, School of Biological Sciences, Queen Mary College, University of London, Mile End Road, London E1 4NS, United Kingdom.

An electrical recording technique has been used to assess the detailed feeding behaviour of Auchenorrhynchan rice pests in response to sub-lethal insecticide concentrations delivered by foliar and by systemic application. In particular the effects of nitromethylene heterocycle compounds (Shell Research) on feeding of the rice brown planthopper *Nilaparvata lugens* (Stal) (Homoptera Delphacidae) and of the Green Leafhopper *Nephotettix cincticeps* (Homoptera Cicadellidae) have been investigated. This technique and others have also been used to examine the influence of environmental variables, relative humidity and temperature on brown planthoppers feeding in laboratory experiments.

WIDE INHERENT VARIATIONS IN WING-FORM RESPONSES TO DENSITY OF THE BROWN PLANTHOPPER, *NILAPARVATA LUGENS* (HOMOPTERA: DELPHACIDAE). S. Tojo*, K. Iwanaga and S. Morooka, Faculty of Agriculture, Saga University, Saga 840, Japan.

Japanese populations of *N. lugens* collected in fields could be classified into several groups by wing-form responses of the females to nymphal density under uniform laboratory conditions: dominant ones exhibited higher ratios of macropters with increasing density, but some showed extremely high proportion of brachypters, some were predominantly macropters in broad ranges of density, and the others showed intermediate responses among these. These wing-form and density relationships were inherent, and successive selections of macropters or brachypters from a group for ten generations could produce totally macropterous or brachypterous population. All of the populations from Indonesia, Malaysia and Philippines were highly brachypterous, where macropterous populations might be reduced by natural selection due to their emigration to other areas. These results indicate that this planthoppers in Japan, which are known to be unable to overwinter, are derived from different migration sources, possibly also from South Asian countries. The development of populations which respond to density in various degrees can be accepted to be highly adaptive for a migratory species to survive in unstable circumstances.

LANDING PLACES OF MIGRATORY PLANTHOPPERS, *NILAPARVATA LUGENS* STAL AND *SOGATELLA FURCIFERA* HORVATH (HEMIPTERA: DELPHACIDAE) IN JAPAN. T. NODA AND K. KIRITANI, DIVISION OF ENTOMOLOGY, NATIONAL INSTITUTE OF AGRO-ENVIRONMENTAL SCIENCES, KANNONDAI 3-1-1, TSUKUBA, IBARAKI 305, JAPAN.

N. lugens and *S. furcifera* are both major rice pests in Japan. Since they have no diapause stage, they are not able to survive the winter in Japan because of low temperature and lack of host plants. They are likely to be originated from mainland China.

There are special places called *Tsubo*, or a low land paddy field where first landing of planthoppers is most likely to occur and where rice plants are vulnerable to hopper-burn. Nation-wide survey questionnaires in 1986 and 1987 on *Tsubo* were made. The *Tsubo* was able to identify by both topographical conditions and the wind direction.

For example, on the coast of the Sea of Japan, most of the *Tsubo* were located on the east side of a hill where westerly wind drifts. Migration of planthoppers to Japan takes place in the rainy season (usually early June to middle July) when the prevailing wind is south-westerly. Therefore, the airborne insects will land on the opposite side of the hill. The identification of the *Tsubo* will help to forecast the incidence of migratory planthoppers.

THE OCCURRENCE OF BROWN PLANTHOPPER, *NILAPARVATA LUGENS* STAL, ON RICE FIELDS IN RELATION TO THEIR IMMIGRATION TIMING AND SUBSEQUENT TEMPERATURE CONDITIONS IN KOREA. Y. H. Song, Department of Plant Protection, Gyeong-Sang National University, Chinju 620, Republic of Korea.

Intensive field observations of brown planthopper (BPH) population density changes on rice, together with laboratory experiments of temperature dependent growth rate and fecundity of BPH, were made to identify the governing factors affecting the late season BPH outbreaks in Korea.

The BPH density rapidly increased to the damaging level when they immigrated before early July, while almost no damage was observed when they came after early July. The amount of immigration seemed to be less important compared to the timing of immigration in terms of the late season BPH outbreaks in Korea.

A simple distributed time delay phenology model, based on the laboratory reaction of BPH growth and fecundity to the various temperature conditions, successfully simulated the timing of BPH occurrence after their immigration on rice fields, however, it is still insufficient for predicting the amount of BPH occurrence in late rice growing season in Korea.

JUDICIOUS USE OF INSECTICIDES TO SUPPRESS BROWN PLANTHOPPER, *NILAPARVATA LUGENS* STAL, POPULATION ON THREE RICE VARIETIES. J. Soejitno*, Wayan Laba and Tarso Sumpena, Bogor Research Institute for Food Crops (BORIF), Jalan Cimanggu Kec 2, Bogor, Indonesia.

Citanduy, Cipunegara and Pelita I/1, rice varieties, respectively, resistant, moderate resistant and susceptible to *Nilaparvata lugens* (BPH) were evaluated. Bpmc, buprofezin and fenitrothion were applied after reaching population density of 5 hoppers/hill at 2-4 weeks after transplanting, 10 hoppers at 5-7 weeks after transplanting and 20 hoppers at booting and maturing stage. On Citanduy the number of BPH was below threshold, less than 5 hoppers/hill up to 9 weeks after transplanting, so that no insecticide application was needed. On untreated Cipunegara the BPH density was high, 324 hoppers/hill. Buprofezin and bpmc, respectively with 2 and 4 applications, effectively suppressed BPH build up and the number of hoppers recorded were 6 and 7/hill. Fenitrothion applied 7 times could not keep BPH below threshold and the number of hoppers recorded was 261/hill at 9 weeks after transplanting. On untreated Pelita I/1 BPH numbers were 217/hill. One application of buprofezin kept BPH below threshold compared to 4 applications with bpmc, and the number of hoppers were 7 and 18/hill, respectively. Fenitrothion applied 8 times failed to suppress population increase and the number of hoppers recorded was 115/hill.

OBSERVATIONS ON *AGAMERMIS UNKA* KABURAKI AND IMAMURA (NEMATODA : MERMITHIDAE), A NEMATODE PARASITE OF *NILAPARAVATA LUGENS* (STAL) (HOMOPTERA : DELPHACIDAE). H. Y. Choo, J. B. Kim and H. K. Kaya, Department of Agricultural Biology, Gyeongsang National University, Jinju 620, Korea and Division of Nematology, University of California, Davis, CA 95616, U.S.A.

Ecological study of *Agamermis unka*, a nematode parasite of *Nilaparvata lugens* was observed in Gyeongnam province, Korea. No significant difference in nematode parasitism between 1st or 2nd generation, paddy fields near or away from sea and daily or annual variation. It was also observed no difference in the soil distribution of nematodes when agrichemicals were treated as folia spray for control of brown planthopper. The nematodes were usually distributed within 5 cm in the soil, but no trend depending on seasons and seemed to be subject to soil conditions. There were significantly differences between brachypterous or macropterous form, sites collected and rice paddy treated or untreated agrichemicals. There showed different parasitism depending on kinds of agrichemicals, namely, it was lowest Cabofuran treatment by 2%, followed by Cartap G. 10%, BPMC D. 15% compared with control 35.29%.

SUSCEPTIBILITY OF DIFFERENT TOMATO VARIETIES FOR THE ERIOPHYID MITE *ACULOPS LYCOPERSICI* (MASSEE) WITH REFERENCE TO THE PREDATION EFFICIENCY OF *TYDEUS CALIFORNICUS* (BANKS) (ACARI: TYDEIDAE). A.A. Osman*, S.M. Abo-Taka and A.M. Zaki, Plant Protection Department, Faculty of Agriculture, Menoufia University, Shebin El-Kom, Egypt.

Comparative population studies of this eriophyid mite showed that tomato varieties differed in their susceptibility. Peto-86 was the highest infested variety all over the three periods of tomato planting, followed by U.C. 97-3, while prichard (local variety) was the least. Regarding the normal distribution of *Aculops lycopersici* (Massee), it was found that serious infestation occurred during summer and Nile periods, causing great damage to the crop, while the least occurred during winter. The peak of infestation generally occurred in May, February and April for the three cultivation periods, respectively. Concerning the efficiency of *Tydeus californicus* (Banks) as a predator, results revealed that an adult female consumed 40.1 ± 1.63 moving stages or 21.27 ± 0.52 eggs of the eriophyid mite per day, respectively.

PREDACEOUS MITES OF EGYPT AND THEIR POTENTIAL USE IN BIOLOGICAL CONTROL STRATEGIES. ALY H. RASMY, Plant Protection Dept., National Research Centre, Dokki, Egypt.

The number of predaceous mite species recorded in Egypt is about 160 species. This remarkable number is almost equal to that of both phytophagous and scavenger mites. The most widely distributed predaceous mites belong to the families Phytoseiidae (35 spp.), Cheyletidae (24 spp.) Tydeidae (19 spp.) and Stigmaeidae (12 spp.). Studies revealed that the complex of predaceous mites plays an important role in regulating the populations of acarine pests in orchards. 25 species of predaceous mites were recorded on citrus trees and 28 species were encountered on deciduous fruit trees. Natural control of the citrus brown mite has been achieved after three years of discontinuing pesticide applications in orange orchards as a balance between the phytophagous mites and the predaceous mites was performed. *Phytoseiulus persimilis* has been introduced recently into Egypt to control the spider mites in greenhouses.

BIOLOGICAL CONTROL OF WESTERN FLOWER THRIPS IN COMMERCIAL GREENHOUSES USING THE PREDATORY MITE *AMBYLSEIUS CUCUMERIS* (ACARINA: PHYTOSEIIDAE). D.P. Elliott, Applied Bio-Nomics Ltd., P.O. Box 2637, Sidney, British Columbia, Canada V8L 4C1.

The use of *A. cucumeris* to control western flower thrips was tested in the laboratory in 1985 and in 4 commercial greenhouses in 1986. Results have been encouraging and in 1987, 38 commercial greenhouses in British Columbia and Alberta used the predatory mite. Control was generally satisfactory on sweet peppers when 50,000 mites per ha were released weekly from February through July and on cucumbers when 200,000 per ha were released weekly over the same period. Control of thrips was unsatisfactory in fall cucumbers in 10 greenhouses because the predators diapaused.

VALIDATION OF A STOCHASTIC MODEL TO SIMULATE SPIDER MITE PREDATOR-PREY INTERACTIONS. D.J. Horn*, D.K. Pearl and R. Bartoszyński, Department of Entomology and Department of Statistics, The Ohio State University, Columbus, Ohio 43210 USA.

A stochastic simulation model of the *Tetranychus urticae* - *Phytoseiulus persimilis* interaction was programmed on a Cray X-MP/24 computer. The model treats as stochastic processes all events except plant growth and miticide decay. Sensitivity analysis indicated that changes in temperature had the largest impact on subsequent demography. Results of computer simulations fit well with demographic data from mite populations confined on single Lima bean plants in a greenhouse. Experiments are underway on larger laboratory "universes" to investigate mite dispersal and response to pesticides.

COMPARISON OF THE EFFECTIVENESS OF TWO PREDACIOUS MITE SPECIES UNDER LABORATORY CONDITIONS. L.P.S. van der Geest*, J.N.M. Calis and W.P.J. Overmeer, Laboratory of Experimental Entomology, University of Amsterdam, Kruislaan 302, 1098 SM Amsterdam, The Netherlands.

The most abundant predacious mite species in apple orchards in The Netherlands are *Typhlodromus pyri* Scheuten and *Amblyseius potentillae* (Garman) (Phytoseiidae). Only the former species is capable to control phytophagous mite species successfully, although *A. potentillae* has a much higher predation capacity and a higher r_m -value under optimal conditions. The two species were compared in the laboratory under optimal and suboptimal conditions with respect to predation capacity and reproductive potential.

BIOLOGY, PROTECTION AND UTILIZATION OF *AMBYLSEIUS ORIENTALIS* EHARA (ACARINA: PHYTOSEIIDAE) IN CITRUS ORCHARDS. Zhu Zhimin and Liu Shigui, Biology Department Jiangxi University, Nanchang, Jiangxi, P.R. of China.

This paper deals with some biological characteristics of a predator, *A. orientalis*, and the methods utilized by us to control red spider mite in Jiangxi citrus orchards. The developmental duration of one generation of the predator is 27.3 days (female), or 15.7 days (male) at a mean house temperature of 30.3°C. Each predator can lay 11 to 45 eggs in its lifetime, and the ovipositional duration is 7 to 23 days. *A. orientalis* preys upon red spider mites. The average total number it eats in its lifetime is 130.97 (female), or 86.97 (male). There are two times during the year, May through June and September through October, when the population of the predator is at its height. The adult predators survive the cold winter by burrowing into old twisted leaves covered with spider webs. During the winter, the predators have no obvious diapause. Some methods of protecting the predator and encouraging its reproduction have been adopted, such as creating artificial mass culture and growing plants which provide suitable habitats and food in order to decrease population of red spider mite and increase population of the predator.

VARIATION IN THE SPATIAL DISTRIBUTION OF TWO SPIDER MITE SPECIES WITH REGARD TO THEIR RELATIVE ABUNDANCE AND MICROCLIMATE OF GRAPEVINE CANOPY. R.H. Hanna*, L.T. Wilson and D.L. Flaherty, Department of Entomology, University of California, Davis, California 95616.

Two spider mite species, *Tetranychus pacificus* and *Eotetranychus willamettei* commonly occur on grapevines in the San Joaquin Valley of California. Detailed investigations of their biology on grapevines indicate that the pattern of their spatial distribution vary with their abundance and with variations in canopy temperatures. In general, *T. pacificus* prefers the exposed (warm) regions of the canopy, whereas *E. willamettei* prefers the shaded (cooler) regions. However, in the absence, or low abundance, of *T. pacificus*, *E. willamettei* is distributed more or less uniformly throughout the vine canopy. Conversely, if *T. pacificus* is abundant, *E. willamettei* is restricted in its distribution to the shaded regions of the vine canopy, thus indicating probable competitive exclusions of *E. willamettei* by *T. pacificus*. Also discussed is the relative importance of these findings with regard to monitoring the abundance of these species for the purpose of estimating their damage levels.

THE EFFECT OF SOME PESTICIDES ON THE BIOLOGICAL ASPECTS OF THE PREDATORY MITE *AMBLYSIUS GOSSIPI* EL-BADRY, E.A.ZANATY, MOHSEN S.TADROS² & A. EL-SHERBINI¹. 1. Biol. Dept., Fac. of Education, Tanta Univ., 2 & 3 Plant Protect. Dept., Fac. of Agric., Tanta Univ., Kafre El-Sheikh, Egypt.

The present work aimed to study the effect of 5 pesticides on both *A. gossipi* and *Tetranychus cucurbitacearum*, Sayed. The LC_{50} of the selected pesticides on both predator and prey were evaluated.

Results indicated that neuron was the most toxic compound to *T. cucurbitacearum*, (LC_{50} = 19ppm) and was the least toxic to the predatory mite *A. gossipi*, (LC_{50} = 250 ppm). The other applied insecticides were different in its toxicity, however, they were always more toxic to the predator. All pesticide applications affected *A. gossipi* adults and a decrease of egg laying capacity, hatchability and food consumption was clear. On the other hand, an increase happened in both egg incubation period, larval and nymphal stages. The measure of biological parameters indicated most toxicity to baythroid and least to sumicidin, lannate and dursban came in between.

THE RESISTANCE TO ACARICIDES AND THE CONTROL EFFICIENCY OF THE CITRUS RED MITE, *PANONYCHUS CITRI* (MCGREGOR) (ACARINA: TETRANYCHIDAE). Kang-chen Lo*, and Tze-kann Wu, Department of Applied Zoology, Taiwan Agricultural Research Institute, 189, Chungcheng Road, Wufeng, Taichung, Taiwan, ROC.

The citrus red mites, *Panonychus citri* were collected from citrus orchards in Kuanhsi, Wufeng and Chuchi and tested in the laboratory for their resistance to acaricides and an ovicide. The resistance ratio of Chuchi strain of the citrus red mite to ethion, azocyclotin and Kuanhsi strain to ppps, oxythioquinox were all above 10 (compare with the Wufeng strain), benzomate dinobuton, prothoate, amitraz, fenpropathrin and nissol were more toxic to female adult mites than other acaricides. Benzomate and nissol were tested more safe to the predatory mite, *Amblyseius herbicolus* (Chant), can be used as selective acaricides in IPM programs. While amitraz and fenpropathrin were highly toxic to *A. herbicolus*. Hexythiazox was more toxic to eggs of the citrus red mite than amitraz. No hexythiazox resistance in the eggs of this spider mite was found.

FIELD TESTS TO CONTROL SPIDER MITES ON APPLE IN THE EASTERN U.S.A. USING CLOFENTEZINE AND HEXYTHIAZOX.

R. W. Weires, Hudson Valley Laboratory, P. O. Box 727, Highland, New York, U.S.A. 12528.

Tests were conducted in Hudson Valley apple orchards from 1984-1986 with the miticides clofentezine and hexythiazox. Both materials effectively controlled European red mite and twospotted spider mite populations, but not those of the apple rust mite. The total amount of material required for seasonal control was least where the materials were used during early summer as spider mite populations reached densities greater than two mites per leaf but less than seven mites per leaf. This timing was usually achieved by the use of early (prebloom) spray oil which controlled or greatly reduced the overwintering European red mite population. Hexythiazox was approximately twice as active as clofentezine in providing spider mite control on an active ingredient basis. Neither material appeared to be toxic to any of the mite predators found in this study, including the coccinellid, *Stethorus punctum* LeConte, the stigmastid, *Zetzellia mali* (Ewing), and the phytoseiid, *Amblyseius fallacis* (Garman).

DEVELOPMENT OF A STRATEGY FOR THE CONTROL OF *TETRANYCHUS URTICAE* KOCH AND *PANONYCHUS ULMI* (KOCH) (ACARINA: TETRANYCHIDAE) IN AUSTRALIAN APPLE ORCHARDS. W.G. Thwaite* and C.C. Bower, Department of Agriculture New South Wales, Agricultural Research and Veterinary Centre, Orange, N.S.W., Australia 2800.

The predatory mites, *Typhlodromus occidentalis* and *T. pyri* have been released in many apple orchards in Australia to control *T. urticae* and *P. ulmi* respectively. However, some growers have continued to rely on regular applications of miticides. The withdrawal of cyhexatin and azocyclotin in 1987 seriously restricted the range of available miticides. The confirmation of high levels of resistance to the new ovicides, clofentezine and hexythiazox in *T. urticae* from ornamentals, also during 1987, further emphasised the fragility of control based on chemicals. An integrated mite control strategy was formulated for the 1987/88 season following a meeting of research workers, the chemical industry and grower representatives in July 1987. Operation of this strategy is discussed.

CLASSICAL BIOLOGICAL CONTROL OF THE CASSAVA GREEN MITE, *MONONYCHELLUS TANAJOA*, IN AFRICA. J. S. Yaninek*, B. Megevan and A. Klay, Africa-wide Biological Control Programme, International Institute of Tropical Agriculture, Station du Benin, B.P. 06-2523, Cotonou, République Populaire du Benin.

In the early 1970s, the Cassava Green Mite (CGM), *Mononychellus tanajoa* (Bondar) (Acari: Tetranychidae), a spider mite of Neotropical origin, was discovered attacking cassava, *Manihot esculenta* Crantz, in East Africa. This mite has since spread across 27 countries in the cassava belt of Africa, causing yield losses estimated at 13 to 80% in a crop that is the principle source of carbohydrates for more than 200 million people. In 1983, the Africa-wide Biological Control Programme initiated a project to control CGM using classical biological control. In Africa, detailed laboratory and field studies were initiated to determine the nature and extent of the CGM problem, and to provide the biological background for future impact studies. In the Neotropics, exploration for natural enemies is being undertaken in agrometeorological homologues of ecological areas in Africa where severe CGM damage occurs. Phytoseiid predators have been selected as the primary agents for introduction. Seven exotic species are presently being reared and experimentally released in Africa. Development of mass rearing technologies and practical field procedures for collaborating national programmes are the principal applied research activities. This project is a multi-disciplinary research effort including international expertise in systematics, crop physiology, behaviour, ecology, economics, and simulation modelling. The goal is to control CGM in Africa while understanding the ecological processes involved.

MASS PRODUCTION OF PHYTOSEIIDS: 1. EVALUATION ON EIGHT HOST PLANTS FOR THE MASS-REARING OF *TETRANYCHUS URTICAE* KOCH AND *T. KANZAWAI* KISHIDA (ACARINA: TETRANYCHIDAE). Wen-Tai Lee, Chyi-Chen Ho* and Kang-Chen Lo

In order to continuously produce the largest quantity of host plant for the mass-production of spider mites, *Tetranychus urticae* Koch and *T. kanzawai* Kishida, from the least space and the lowest cost, a method using the rice seedling-nursery box (60 x 30 x 3 cm) was developed. A soybean native variety, Chin-pe Tou, was chosen as the host plant for the mass-production of spider mites based on the consideration of the cost of seeds, growth vigor of plant, and reproduction rate of the spider mite. Comparing the leaf weight, leaf area and plant height at various planting densities, 900 seedlings per box was considered the most economic cultivating practice. Informations on the control of the various soybean pest were given.

TETRANYCHID MITES (ACARI: TETRANYCHIDAE) INJURIOUS TO PLANTS IN KHUZESTAN, IRAN. K. KAMALI, COLLEGE OF AGRICULTURE, SHAHID CHAMRAN UNIVERSITY. AHVAZ. IRAN

In 1986 a faunistic survey was initiated to collect and identify mites (Acari) associated with economic plants in Khuzestan, Iran. Several species from orders Prostigmata and Mesostigmata were collected and duly identified. Only injurious tetranychids of the area and their host plants are included. During 18 months of surveying, a total of 11 species from 3 tribes were collected. Among them, 5 species were ^{new} record to Iran which are marked by an asterisk. They are listed according to their tribes names. (A). Bryobiini, (1) *Bryobia praetiosa* Koch. Collected from barley and rye, (2) *Pseudobryobia** sp. collected from wild safflower, and (3) *Petrobia* (*Mesotetranychus*)* sp. collected from wheat and barley. According to E.W. Baker (personal communication) the latter 2 species are possibly undescribed. (B). Eurytetranychini, (1) *Eutetranychus orientalis* (Klein), collected from citrus spp. and 27 other plant species, (2) *E. palmatus** Attiah collected from date palm, (C). Tetranychini, (1) *Eotetranychus lewisi** (McG.) collected from fig, (2) *Eotetranychus** sp. Collected from apple and apricot, (3) *Tetranychus turkestanii* (U. & N.) collected from soybean and 36 other plant species, (4) *Oligonychus sacchari* (McG.) collected from sugarcane (5) *O. zeae** (McG.) collected from sugarcane and corn, and (6) *O. afraasiaticus* (McG.) a serious pest of date palm in the area.

COMPARISON OF *RHINOCYLLUS CONICUS* FROEL. AND *TRICHOSIROCALUS HORRIDUS* (PANZER) AS BIOLOGICAL CONTROL AGENTS OF *CARDUUS* THISTLES. L.T. Kok, Department of Entomology, Virginia Polytechnic Institute & State University, Blacksburg, Virginia, U.S.A. 24061

Two introduced European weevils, *R. conicus* and *T. horridus*, are well established on *Carduus* thistles in Virginia. Release sites with reductions exceeding 75% in thistle density are common. *R. conicus*, which attacks the thistle head, is more conspicuous, establishes more easily, and produces a more visible impact on musk thistle (*Carduus theomeri* Weinmann) than *T. horridus*. However, its impact is less dramatic on plumeless thistle (*Carduus acanthoides* L.) and *R. conicus* tends to disperse rapidly once the thistle population declines to a low level. *T. horridus*, which attacks the rosette stage, takes longer to become noticeable. Although it prefers musk thistle, it is effective on both musk and plumeless thistles. *T. horridus* maintains its presence at a site after the thistle population declines. By overwintering in the egg, larva and adult stage, *T. horridus* survives low winter temperatures better than *R. conicus*, which overwinters only as adults. The two weevils complement each other and provide better control of *Carduus* thistles than each acting on its own.

COMBINED EFFECT OF TEMPERATURE AND PHOTOPERIOD ON THE INDUCTION OF REPRODUCTIVE DIAPAUSE OF THE CARROT WEEVIL, *LISTRONOTUS OREGONENSIS* (LE CONTE) (COLEOPTERA: CURCULIONIDAE). G. Boivin, Research Station, Agriculture Canada, Saint-Jean-sur-Richelieu, Quebec, Canada J3B 6Z8.

The reproductive diapause of the carrot weevil was studied by subjecting newly emerged adults to various combinations of photoperiod and temperature. At 20°C, the optimal photoperiod was 16 light (L): 8 darkness (D). No oviposition took place from 14L: 8D to 6L: 18D but it resumed from 4L: 20D to 0L: 24D. Increasing temperature decreased the response to the photoperiod. At 24°C and 28°C, oviposition occurred at all photoperiods although it was much lower from 14L: 8D to 6L: 18D. Carrot weevil females responded to the length of the light period but not to the length of the dark period. Under a fixed photoperiod of 18L: 6D and a thermoperiod of 16°C: 24°C, only 24 (16°C): 0 (24°C) significantly decreased the mean number of eggs laid per female after 800 degree-days (base 7°C). Thermoregulation of photoperiod response would allow for a second generation of carrot weevil in warm seasons.

DEVELOPMENT OF THE SWEETPOTATO WEEVIL PHEROMONE FOR USE IN AN IPM PROGRAM. A. M. Hammond, Jr.* and S. J. Toth, Jr., Department of Entomology, Louisiana State University, Baton Rouge, Louisiana, 70803 U.S.A.

The sweetpotato weevil, *Cylas formicarius elegantulus* (Summers), is a serious pest of sweet potato, *Ipomoea batatas* (L.) Lam., both in field and storage. Synthetic (Z)-3-dodecen-1-ol-(E)-2-butenate, the female-produced sex pheromone, is being developed for use in survey and detection programs. Currently our research efforts center on determining the optimal pheromone-trapping system. Results of studies on trap design, pheromone purity, dosage, longevity and the efficacy of different commercial pheromone lure formulations will be presented. A sensitive pheromone-based tool for detecting and monitoring both population changes and movement by the sweetpotato weevil would facilitate pest management practices.

SCREENING FOR RESISTANCE TO SWEET POTATO WEEVIL, *EUSCEPES POSTFASCIATUS* (FAIRMAIRE) IN THE SWEET POTATO GERMPLASM. K. V. Raman* and M. Palacios, Department of Nematology and Entomology, International Potato Center, P. O. Box 5969, Lima, Peru.

The sweet potato weevil, *Euscepes postfasciatus* (Fairmaire) is one of the most serious pests attacking sweet potato (*Ipomoea batatas* (L.) Lam.) in South and Central America. A laboratory screening method to identify resistance in storage roots has been developed. 700 accessions from the sweet potato germplasm maintained at the International Potato Center (CIP), Lima, Peru were tested. In the first test, 2 roots/accession were infested individually with 10 adult weevils. Damage and population development was appraised 60 days after infestation. Of the total screened, 23 accessions were selected for further trials using 5-8 replicates per accession. In this second test, 6 accessions RCB 68, 189, 280, 543, 561.H and DLP 189 were selected. Weevil population development and damage in these clones was significantly reduced indicating the possibility of an antibiosis resistance mechanism. These promising clones are now being tested in farmer's field infested heavily with *E. postfasciatus*.

FALL AND SPRING MIGRATIONS OF PLUM CURCULIO (COLEOPTERA: CURCULIONIDAE) IN SOUTHERN QUEBEC. G. Lafleur* and S.B. Hill, Department of Entomology, Macdonald College of McGill University, Ste-Anne-de-Bellevue, QC., Canada H9X 1C0.

A new technique for applying the isotope ⁶⁵Zn to the body surface of plum curculio (PC) *Conotrachelus nenuphar* (Herbst), is presented. More than 5000 labeled adult PC were released in orchards, woodlots, and microplots in a plowed field. In fall, from orchards, most PC migrated toward high tree silhouettes at the edge of woodlots unless they occurred to the north. Migration was influenced by woodlot type and direction. Where woodlots had a thin litter layer, PC remained at the edge or returned to the orchard.

PC that migrated to adjacent woodlots in fall, re-infested the orchard in spring. Spring migration is thought to include both a mass migration in a preferred direction (the reverse of fall migration direction) and an exploratory component by which PC seek optimal feeding and oviposition sites. Implications for control and future research are discussed.

SPATIAL EXPANSION OF A NEWLY COLONIZED INSECT, RICE WATER WEEVIL (*LISSORHOPTRUS ORYZOPHILUS*), IN JAPAN. Nobuo Morimoto, Division of Entomology, National Institute of Agro-Environmental Sciences, Kannondai, Tsukuba, Ibaraki, Japan 305.

The rice water weevil (RWW), which likely originated from California, is currently one of the major pests of rice in Japan. Since its first discovery in 1976 in Nagoya, Aichi, central Japan, it was distributed all over Japan by 1986. The expansion rate, measured in terms of annual increase in the infested area, was greater in northern Japan than in southern Japan. Since the development of flight muscle depends on temperature, the spring migration to paddy fields from overwintering sites takes place earlier in southern Japan. Rice is transplanted, however, much later in southern Japan than in the north. Therefore, the spring migration tends to occur before the presence of rice plants in the production fields in southern Japan. This results in a low reproductive rate of RWW and makes the expansion rate low in southern Japan.

TRAP CROPS AS DECISION-MAKING TOOLS IN THE CONTROL OF *APION GODMANI* WAGNER (COLEOPTERA: CURCULIONIDAE) IN HONDURAN DRY BEANS. R. D. Cave*, H. E. Portillo, K. L. Andrews, G. Cerritos and I. Navarrete, Department of Plant Protection, Escuela Agrícola Panamericana, Apartado 93, Tegucigalpa, Honduras.

Two types of trap crop plots were evaluated for their efficiency and economic feasibility as decision-making aids for control of the bean pod weevil, *Apion godmani* Wagner, on dry beans. Trap plots planted 20-30 days before the commercial crop consisted of six 3 x 3 m blocks or two 2 x 50 m borders per 1500 m² of commercial crop. For both types, the percentage of damaged beans from 100 pods collected in the commercial crop was highly correlated with the percentage of damaged beans from 100 pods collected 30 days earlier in the trap crop. There was no significant difference between correlations for both trap crop types. However, the square blocks were more economical than the borders. Therefore, economic injury levels and action thresholds were lower with square blocks than with borders. Small blocks have a greater risk of destruction by pests earlier in the season.

EFFECTIVENESS OF PLANT OILS USED AS SURFACE PROTECTANTS FOR CHICKPEA *CICER ARIETINUM* L. AGAINST PULSE BEETLE *CALLOSOBROCHUS CHINENSIS* (L.) SHIV K. Singal* and Zile Singh, Department of Entomology, Hisar, 125004, India.

Plant oils namely groundnut, coconut, mustard, sesame, soybean and rapeseed used @ 1, 3, 5 ml/kg of seed to test their efficacy as surface protectants against *C. chinensis* on chickpea variety H-81-73 resulted in significantly less oviposition on treated than untreated seeds. Least oviposition (34.3 eggs) occurred on seeds treated with mustard oil @ 5 ml/kg which though on par with coconut oil used @ 5 ml/kg (46.0 eggs) and 3 ml/kg (47.3 eggs) yet differed significantly from the rest. Minimum percentage adult emergence (0.5) occurred from mustard oil treated seeds @ 5 and 3 ml/kg which differed significantly from that of groundnut (7.6), soybean (16.7) and rapeseed (6.2) oils used @ 1 ml/kg. All the test oils possessed/exhibited properties which adversely effected hatching/development of embryos resulting in further population suppression. Treated seeds were practically free from beetle damage showing only 0.5% damage in mustard oil treated seeds used @ 5 and 3 ml/kg and rapeseed 5 ml/kg. Oil treatments did not produce any adverse effect on seed germination.

FLAMING, AN EFFECTIVE METHOD FOR CONTROLLING THE ALFALFA WEEVIL *HYPERA POSTICA* (GYLLENHAL). Ali Asghar Seraj* and M. Esmaeli, College of Agriculture, Department of Entomology, Karaj, Iran.

Flaming trash and stubble in alfalfa fields during late autumn and winter against eggs and hibernating adults of the alfalfa weevil was done during 1986-1987. The results reveal that this method is significantly effective in lowering the population density of this pest in the following spring and increases the alfalfa yield. Flaming not only destroyed the insect pest, but also was effective against many annual weeds, and dodder. Biological tests of soil inhabiting fauna showed that under experimental conditions no significant negative effects were detected. The destruction of hibernating beneficial arthropods on the soil surface was not more than that of insecticides.

IMPACT OF INSECTICIDES ON PLANT GROWTH AND ON APPEARANCE/SUPPRESSION OF INSECT PEST AND BEE POPULATION AT MUNG BEAN. H.C.L. Gupta*, R. Swaminathan, Man Singh and K.L. Jain Department of Entomology, Rajasthan College of Agriculture, Udaipur 313 001 INDIA.

Effective control of grey weevil (*Mytillocerus maculosus* Desb.), black weevil (*Cyrtosemia cognata* Marshall) on mung bean (*Vigna radiata* L.) crop by the foliar spray of 0.0375% acephate, 0.005% permethrin, 0.005% cypermethrin, 0.005% decamethrin and 0.036% monocrotophos without showing phytotoxicity and adverse insignificant effect on bee visit was achieved with increased crop yield. As high as 0.225% acephate, 0.225% permethrin, 0.225% cypermethrin, 0.0504% decamethrin and 0.432% monocrotophos did not show any toxicity to mung bean plants but showed the repellancy to bee faunal visit. No harvest time residue of synthetic pyrethroid in mung bean was measured.

A DYNAMIC ECONOMIC THRESHOLD (ET) FOR CONTROLLING THE ORIENTAL ARMYWORM (*MYTHIMNA SEPARATA* W.) ON WINTER WHEAT IN CHINA. Xiang-yao Su* and Chang-shan Lin, Department of Biology, Peking University, Beijing, China.

By coupling plant-pest-predator models and simulating on a daily time step, the dynamic economic threshold for pest management can be computed for various developmental stages of winter wheat and various densities of the predator, *Calosoma chinense*. This study includes three models, the plant (wheat) model, the pest (armyworm) model, and the predator (*C. chinense*) model. Two types of pesticides are used to control armyworm in fields with wheat yields above 3750 kg/ha in the Zhumadian district of Henan province. In the absence of the predator, *C. chinense*, economic threshold is computed to be in the range of 22-34 pest larvae/m² when armyworm powder is used for control and 14-23 pest larvae/m² when Dimilin is used. These ranges are based on field experience. The simulation results show that the earlier the armyworm appears, the smaller the value of economic threshold. However, when the predator is present it exerts a significant influence on the economic threshold. For the same developmental stage of wheat, economic threshold increases with increasing number of predator. Clearly, the effect of *C. chinense* on economic threshold changes as temperature and armyworm densities change. When there is an increment of 0.02 predators/m² the corresponding economic threshold increases by 1-3 pest larvae/m².

EFFICACY OF DIFFERENT INSECTICIDES FOR THE CONTROL OF *MYTHIMNA SEPARATA* WALKER (LEPIDOPTERA: NOCTUIDAE) INFESTING *ZEA MAYS* DURING WINTER. S.S.Sekhon*, Uma Kanta and S.S.Sajjan, Department of Plant Breeding, Punjab Agricultural University, Ludhiana-141 004, India.

The efficacy of different insecticides such as Thioclor 35 EC (endosulfan) 190, 250, 315 and 625 ml; Sevin 50 WP (carbaryl) 190, 250, 315 and 625 g; Killex 50 WP (carbaryl) 625 g; Cymbush 25 EC (cypermethrin) 20, 30, 40 and 80 ml; Sumicidin 20 EC (fenvalerate) 50, 75, 100 and 200 ml as sprays and granules of Furadan 3G (carbofuran) and Sevin 4G each 1.25, 2.50 and 3.75 kg and Thimet 10G (phorate) 2.50 kg as whorl application (all dosages/ha) was evaluated for the control of *Mythimna separata* Walker infesting winter maize during 1984 to 1987. Thioclor 35 EC 315 and 625 ml, Sevin 50 WP 625 g, Cymbush 25 EC 80 ml, Sumicidin 20 EC 100 and 200 ml, Furadan 3G 2.50 and 3.75 kg and Sevin 4G 3.75 kg causing 80-100 per cent reduction of the pest population proved consistently very effective in controlling the pest.

FRUIT-PIERCING MOTHS (F. NOCTUIDAE) IN TROPICAL AUSTRALIA: ASPECTS OF THEIR ECOLOGY AND POTENTIAL FOR THEIR CONTROL. H.A.C. Fay, Department of Primary Industries, Mareeba, Queensland 4880, Australia.

In tropical Australia more than 40 noctuid moths have been recorded feeding on the juices of a range of fruits, but 6 species cause the bulk of primary damage to the skin or rind. Subsequent fruit rot and premature fall can result in crop losses of >50%. In NE Australia, *Othreis fullonia* (Clerck) is the dominant pest species, while *Othreis materna* (L.) is the only significant piercer in other monsoonal areas.

The main larval food plant for 5 of the 6 species is the vine *Tinospora smilacina* Benth.. It occurs in 3 forms (of unclear taxonomic status) in separate habitats; 1) rainforest/wet coast, 2) foreshore and adjacent open forest and 3) drier monsoonal areas across northern Australia. The two latter forms are largely leafless during the dry season. Other larval host plants are also used, but all belong to the family Menispermaceae.

Adult activity is most intense in summer and autumn, and carambolas, lychees, paw paws and citrus can suffer heavy damage. Control is difficult as fruits are attacked near maturity (negating insecticide use), larval feeding areas are isolated from adult feeding sites and some moths can migrate hundreds of kilometres. Monitoring and control techniques being examined are 1) pheromones, 2) synthetic fruit scents as baits and/or decoys, 3) light-repulsion methods, and 4) strategic netting (physical barriers).

INTERSPECIFIC COMPETITION BETWEEN FALL ARMYWORM PARASITOIDS *CHELONUS INSULARIS* AND *COTESIA MARGINIVENTRIS* INSIDE FIELD CAGES AND PLOTS. Rohan Rajapakse*¹, Van H. Waddill² and Tom R. Ashley³, (1) Department of Agronomy, University of Ruhuna, Mapalana, Kamburupitiya, Sri Lanka; (2) Everglades Research and Education Center, University of Florida, Belle Glade, Florida, USA; (3) Insect Attractants Behaviour and Basic Biology Laboratory, USDA/ARS, Gainesville, Florida, USA.

Interspecific competition between fall armyworm, *Spodoptera frugiperda* (J.E. Smith), egg parasitoid, *Chelonus insularis*, and larval parasitoid, *Cotesia marginiventris*, was studied inside field cages and plots. *Ch. insularis* emerged most frequently in treatments having 1 or 2 paper sections while *Co. marginiventris* was the major parasitoid in 3 paper section treatments indicating that *Co. marginiventris* was a better competitor in crowded host conditions. The release of the two parasitoids inside the field cages resulted in an overall parasitization rate of 60% for *Ch. insularis* and 37.4% for *Co. marginiventris*. These results indicated that *Ch. insularis* was the principal parasitoid regulating the fall army worm population in Southern Florida.

IMPACT OF HYMENOPTEROUS PARASITOIDS ON *EXELASTIS ATOMOSA* WALSINGHAM (LEPIDOPTERA), A PIGEONPEA PEST IN INDIA. T.V. Sathe, Department of Zoology, Shivaji University, Kolhapur -416 004, India.

Diadegma trichoptilus (Cameron) (Ichneumonidae), *Cotesia orientalis* C. & N. (Braconidae) and *Cotesia diurnii* R. & N. (Braconidae) are endo-larval parasitoids of *Exelastis atomosa* Walsingham. The pest mortality due to these parasitoids was 40% in the fields of Kolhapur, India; *D. trichoptilus* showed 12% while, *C. orientalis* and *C. diurnii* showed 20% and 8% respectively. In the laboratory conditions (26 ± 1°C, 50 ± 3% R.H.) the parasitism recorded by *D. trichoptilus*, *C. orientalis* and *C. diurnii* were 32%, 42% and 20% respectively. All parasitoids attacked 2-4 day old host caterpillars. *C. orientalis* develop relatively fast (15 days) than other parasitoids on the same host. The progeny production was highest (91.1) in *C. orientalis* and lowest (44.6) in *D. trichoptilus*. The mortality of parasitoids due to hyperparasitism was also studied and found its peak in January.

THE INFLUENCE OF FEMALES ON THE CATCH RATE OF THE PHEROMONE TRAP IN TOBACCO CUTWORM (*SPODOPTERA LITURA* FAB.). Y.I.Chu*, and C.J. Shih, Department of Plant Pathol. and Entomol. National Taiwan University, Taipei, Taiwan, R.O.C.

The influence of the female tobacco cutworm on the catch rate of pheromone trap is investigated under the screen house and field condition. Under the screen house of non-female condition, although the No. of provided male varied from 5 to 80, the catch rate always shows in the range of 20 to 30%. While under the sex ratio (♂/♀) of 1/1, the rate decreased around 10%, then 40-65% of provided females are mated within 24 hrs. The similar trend is observed under the various sex ratio from 20/3 to 20/40. If 100♀ is set in 10X10m area, the catch rate of marked male was 7.2%, the mated ratio of female is 56%, while the recovery rate in non-female set area was 20.0%.

COMPONENTS FOR INTEGRATED CONTROL OF *HELIOTHIS ARMIGERA* IN NEW ZEALAND. P.J. Cameron* and G.P. Walker, Entomology Division, D.S.I.R., Private Bag, Auckland, New Zealand.

A recently introduced parasitoid, *Apanteles kazak* Telenga, is the only parasitoid of larval *Heliothis armigera* (Hubner) in New Zealand. It provides insufficient control of this pest in unsprayed vegetable crops therefore attempts are being made to introduce another braconid, *Microplitis croceipes* (Cresson). *A. kazak* attacks smaller larvae than *M. croceipes* and is unlikely to be displaced by *M. croceipes* which normally cannot develop in larvae already parasitised by *A. kazak*. In field trials, *A. kazak* appeared relatively tolerant of permethrin, and parasitism of *H. armigera* was similar to that obtained in plots treated with *Bacillus thuringiensis* Berliner (Bt) or untreated plots. Compared with permethrin, Bt provided inadequate control of *H. armigera* in field tomatoes. Prospects for integrated control of *H. armigera* are discussed.

POPULATION DYNAMICS OF *HELIOTHIS ZEA* (BODDIE) ON CORN IN THE LOWER RIO GRANDE VALLEY OF TEXAS AND TAMAULIPAS, MEXICO: A POSSIBLE MIGRATION SOURCE AREA. J.R. Raulston*, S.D. Pair, J. Loera, W.W. Wolf, J.R. Westbrook and A.N. Sparks.

Heliothis zea is one of the most serious pests of the U.S. cotton industry. However its preferred host, corn (*zea mays*), is considered to act as a nursery crop where large populations of the pest develop which subsequently may migrate long distance to infest other susceptible crops. The Lower Rio Grande Valley which produces 200,000 ha of corn annually is a possible migration source area. Population dynamics studies in this region indicate that an initial *H. zea* infestation of 19.8-42.8% occurs on whorl stage corn between Julian days 90-105. Adults from this population appear to retain residency

MONITORING AND MANAGEMENT OF PYRETHROID RESISTANCE IN THE TOBACCO BUDWORM, *HELIOTHIS VIRESCENS* (F.), IN TEXAS. J. A. Jackman*, Frederick W. Plapp, Jr. and R. E. Frisbie, Extension Entomology and Department of Entomology, Texas A&M University, College Station, Texas 77843.

A treated glass vial monitoring technique was used to test for resistance to pyrethroid insecticides in the tobacco budworm, *Heliothis virescens* (F.), in Arkansas, Louisiana, Mississippi, Oklahoma and Texas in 1987. Tests with more than 34,000 tobacco budworm adult males confirmed the presence of region-wide resistance to pyrethroids and its successful management in areas where pyrethroid use was restricted to the critical midseason period. Similar tests with the bollworm, *Heliothis zea* (Boddie), indicated increased tolerance in 1987. The data indicated continued needs for limiting pyrethroid use to the midseason period and for resistance monitoring.

EFFECT OF LARVAL WEIGHT AND DOSE ON THE TOXICITY OF MALATHION TO *HELIOTHIS ARMIGERA* HUBNER (LEPIDOPTERA: NOCTUIDAE). S. Balasubramanian, Department of Zoology, Bharathiar University, Coimbatore 641 046, India.

Heliothis armigera is a cosmopolitan pest distributed throughout the Old World and has developed resistance to many organic insecticides. Several physicochemical factors influence the development of resistance in insects. Weight is one of the factors affecting the intrinsic susceptibility of insects to insecticides. Variation in larval weight of *H. armigera* was related to variation in the mortality of susceptible and resistant larvae to malathion. It is assumed that percent mortality (Y) is linearly related to log dose (Q) and log weight (W) and represented by the equation $Y = b_1Q + b_2W + C$. For each dose and weight, the data plot as parallel lines with positive and negative slopes. This indicates that there is a clear correlation between these variables and mortality. However, for resistant larvae the relationship is not linear among the factors tested. From this it is assumed that it is log weight and not log dose that is directly involved in resistance mechanisms.

THE USE OF ELEMENTAL ANALYSIS FOR QUANTIFYING INTERCROP MOVEMENT IN *HELIOTHIS* (LEPIDOPTERA:NOCTUIDAE). G.P. Fitt*, A.N. Pinkerton, R. Morton, CSIRO Entomology, Narrabri, Australia, 2390; CSIRO Plant Industry and Mathematics and Statistics, Canberra, Australia, 2600.

Two species of *Heliothis* are major pests of a variety of field crops in Australia, but are particularly damaging on cotton. An understanding of local intercrop movements is crucial to efforts to model the regional dynamics of *Heliothis*, in particular recruitment into cotton crops.

As part of a wider study of *Heliothis* dynamics in multicropping systems a technique has been developed to quantify intercrop movements using natural chemical markers, rather than artificial marking systems. The technique relies on the accumulation of a characteristic profile of elements by larvae feeding on a particular host which is retained into the adult dispersive stage.

Wavelength dispersive x-ray spectroscopy was used to examine the elemental profile of individual moths reared on a range of known hosts. Using 11-13 elements we found consistent differences in elemental profile of moths reared on cotton, maize, sorghum, sunflowers and chickpeas. *Heliothis* spp. and sex had little influence on elemental profile and differences in soil type did not mask discrimination among crop types. Preliminary results and the application of this technique to field studies of *Heliothis* movement will be discussed.

HOST-PLANT PREFERENCE, NUMBER OF GENERATIONS AND POPULATION FLUCTUATIONS OF THE CITRUS FLOWER MOTH, *PRAYS CITRI* MILL. (LEPIDOPTERA: HYPONOMEUTIDAE) AT GHARBA GOVERNORATE, EGYPT. S.A. El-Dessouki, S.M. El-Awady and M.A. Abo-Sheasha, Plant Protection Department, Faculty, Agriculture, Al-Azhar University, Nasr City, Cairo Egypt.

The susceptibility of 6 host-plants to the infestations by the citrus flower moth, *Prays citri* was tested. Lime trees were found to be the most susceptible. Fluctuations in the larval population were investigated through two years (1983 and 1984). The population size of larval infestation was comparatively higher during 1984 than in 1983. Nine peaks a year was estimated. The study indicated that the *Prays citri* had 9 generations a year on lime trees at Gharbia Governorate.

NEW APPROACHES TO THE CONTROL OF THE CODLING MOTH ON APPLE IN THE OKANAGAN REGION OF BRITISH COLUMBIA --- SPRAYS TIMED BY DEGREE-DAYS, OVICIDES, AND STERILE-INSECT RELEASES. V.A. Dyck, Agriculture Canada Research Station, Summerland, British Columbia, Canada V0H 1Z0.

Until recently it was recommended that orchardists spray organophosphate insecticides when the treatment threshold (2 or more moths per sex pheromone trap for 2 consecutive weeks) is reached. It has now been found that, when about 250°D above a base of 10°C have accumulated in a degree-day program, the first spray of the year can be timed to coincide with 3% egg hatch. The current recommendation incorporates both the treatment threshold and the degree-day program.

In a search for insecticides that are more acceptable environmentally than currently used ones, chemicals that interfere with chitin deposition such as diflubenzuron and insect growth regulators such as fenoxycarb were tested in orchards. In the control of the codling moth, these materials are ovicidal; if applied before oviposition, good control was achieved.

A plan to implement a large-scale and long-term sterile insect release program to control the codling moth has been developed by industry and government. The plan includes technical, financial and administrative aspects. Local growers and governments are currently evaluating the plan.

PHEROMONE TRAPS: NEW TOOLS FOR INSECTICIDE RESISTANCE MONITORING IN LEPIDOPTEROUS TREE FRUIT PESTS - AN EVALUATION. H. Riedl* and P. W. Shearer, Mid-Columbia Agricultural Research and Extension Center, Oregon State University, Hood River, OR 97031, USA.

Pheromone traps have found wide application in tree fruit pest management for monitoring lepidopterous pests to establish timing and need for control measures. A recent application is the use of pheromone traps for assessing insecticide susceptibility in field populations. The bioassay procedure consists of treating moths topically shortly after capture in adhesive-coated traps with a small droplet of toxicant to determine the dose-mortality response. The pheromone-trap assay was evaluated for codling moth, *Cydia pomonella* L., and tentiform leafminer, *Phyllonorycter elmaella*, and has given reliable estimates of susceptibility to azinphosmethyl and oxamyl when compared to standard bioassay methods. Applications of the pheromone trap assay as well as its limitations will be discussed. Studies suggest that the pheromone trap could become a useful tool to establish baseline data for insecticide susceptibility, determine discriminating concentration levels for resistance surveys and map the distribution and spread of resistance as it develops in the field.

STUDIES ON THE DIAPAUSE OF THE CODLING MOTH IN ISRAEL. S. Steinberg, H. Podoler and S.W. Applebaum, The Hebrew University of Jerusalem, Faculty of Agriculture, P.O.Box 12, Rehovot, Israel.

A three-year study was conducted in order to quantify the processes involved in diapause induction and termination of the codling moth, *Cydia pomonella* L., in Israel. The accumulated data served for constructing sub-models to be incorporated in a phenology model, PETE, now being implemented in the major apple growing region of Israel.

Diapause induction in field populations of the pest was studied in two commercial apple orchards. Non-linear regression equations were fitted to the data. The role of temperature and larval-diet (modifiers of the photoperiodic response) was determined quantitatively in the field and under controlled conditions. A model, comprising the three major factors affecting diapause induction, has been formulated to provide information concerning the number of generations per season and the timing of the last chemical treatment against the pest.

Another model, describing the relationship between the amount of chilling received during the reactivation period and the pattern of diapause termination, has been formulated to determine the age distribution of the codling moth at the beginning of the season, thus providing the PETE model with a vital input parameter.

DEVELOPMENT OF POSTHARVEST QUARANTINE TREATMENTS TO CONTROL CODLING MOTH (LEPIDOPTERA: TORTRICIDAE) AND ORIENTAL FRUIT MOTH (LEPIDOPTERA: TORTRICIDAE) IN STONE FRUITS. Victoria Y. Yokoyama* and Gina T. Miller, U.S. Department of Agriculture, Agricultural Research Service, Fresno, California, U.S.A. 93727

Laboratory techniques and a formulated diet were developed to mass rear both codling moth (CM) and oriental fruit moth (OFM). A methyl bromide (MB) fumigation of 48 g/m³ for 2 h at 21°C or above with a 50% load factor was developed as a quarantine treatment to control CM in nectarines for export to Japan. A MB fumigation of 30 g/m³ for 2 h at 21°C caused 100% mortality of artificial infestations of OFM eggs and first through fifth instars in nectarines. A short-term high temperature treatment of 45.0°C for 55 min killed all OFM immature stages. Temperatures higher than 46.0°C for 55 min were needed to cause 100% mortality of CM fifth instars. CM eggs exposed for 14 d and OFM first, second and third instars exposed for 21 d failed to reach the adult stage after long-term low temperature storage at 0°C. Insect/plant interaction studies showed certain stone fruit cultivars were either significantly acceptable or not acceptable for oviposition by either CM or OFM.

POSTHARVEST CONTROL OF THE CODLING MOTH, *CYDIA POMONELLA* (L.) (LEPIDOPTERA: TORTRICIDAE), TO MEET QUARANTINE REQUIREMENTS FOR APPLES. H. R. Moffitt*, C. R. Sell, and S. R. Drake, ARS-USDA, Yakima, Washington, U.S.A. 98902.

The codling moth is a quarantine pest of major concern due to interest in exporting apples to Japan and the Republic of Korea, in which countries this important pest is not known to occur. Japanese and Korean import quarantine regulations are stringent and require application of a direct treatment, such as a chemical fumigant, to any fruit known to be a host of the insect before the fruit can be allowed entry. Of the stages of the codling moth, the egg on the fruit and the larva inside are those of concern on apples from the western United States. The egg is the more tolerant to methyl bromide and treatments effective against it can cause unacceptable levels of damage to apples. The egg, however, is more sensitive than the larva to low temperatures and a two-component treatment consisting of a minimum of 55 days at 2.2°C or below against eggs and subsequent fumigation with methyl bromide at 56 m/g³ for 2 hours at 6°C or above provides quarantine control of the codling moth on Red Delicious and Golden Delicious apples with minimal phytotoxic effect. A system based on pest control in the orchard; selective grading and sorting of apples, and, inspection and certification of packed apples has also been developed.

FORECASTING PROBLEMATIC INSECT PEST OCCURRENCE: RISK ASSESSMENT AND THE GRAPE BERRY MOTH, *ENDOPIZA VITEANA* (CLEMENS) (LEPIDOPTERA: TORTRICIDAE), IN NEW YORK VINEYARDS. C.J. Hoffman* and T.J. Dennehy, Department of Entomology, Cornell University, NYSAES, Geneva, New York 14456. USA

Levels of infestation of the grape berry moth in New York State vary dramatically from vineyard to vineyard, from region to region, and from year to year. A number of the environmental factors contributing to this variability have been elucidated. These include overwintering survival, proximity to alternate hosts and wooded edges, presence of natural enemies, patterns of movement, and previous levels of grape berry moth infestation. Several of these factors have been used to predict the severity of grape berry moth attack in a given vineyard during a given year. Using this information, we can separate vineyards in New York into categories of high-, medium, and low-risk. We then can advise growers to tailor sampling methods and treatment strategies to reflect this risk value.

ARCHIPS POMIVORA MEYRICK (LEPIDOPTERA:TORTRICIDAE), A COMMON LEAF ROLLER OF APPLE IN INDIA. T.D. VERMA AND R.CHANDER* DEPARTMENT OF ENTOMOLOGY, D Y S P UNIVERSITY OF HORTICULTURE & FORESTRY, SOLAN 173 230 INDIA.

Twelve species of leaf rollers namely *Archips pomivora* Meyrick, *A.micaceana* Walker, *A.dispilana* (Walker), *A.subsidiaria* Meyr., *A.sarcostega* Meyr., *A.hemixantha* Meyr., *Acleris orphnocycla* Meyr., *Capua* sp., *Acrolita raevana* Hubner, *Peronia agriomma* Meyr., *Ulodemis trigrappa* Meyr., *Mochlophyga humana* Meyr., are known to infest apple in India.

A.pomivora is the most common and predominating species infesting foliage and fruits of apple. It is active from April to November and overwinters as third instar larva. It has three overlapping generations; the first adult appearance is in May whereas, the second and third are in July and September, respectively. Eggs are laid in irregular flat, greenish yellow clusters of 37-178 eggs which hatch in 8-16 days. The pale green with prominent black head, larva passes through six instars in 25-31 days. Pupation is for 6-9 days in leaf folds. Adults differ; male dark brown and female yellowish brown and last for 6-15 days. Larva primarily feeds on foliage of apple from April to September by rolling and webbing tender terminal leaves. However, during August-September it settles at calyx or stalk ends of fruits and scraps the skin in irregular patches. Damage becomes pronounced in packed/wrapped fruits in storage to the extent of 41 per cent.

EFFECT OF DESIGN AND PLACEMENT OF PHEROMONE TRAPS FOR MONITORING APPLE LEAFROLLER ARCHIPS POMIVORA MEYRICK (LEPIDOPTERA:TORTRICIDAE) IN NORTH INDIAN ORCHARDS. S.P. Bhardwaj* and R.Chander, University of Horticulture and Forestry, Regional Research Station, Sharbo, Kinnaur, H.P.India 172 107.

Apple leafroller *Archips pomivora* Meyrick, the predominant tortricid infesting apple in Himachal Pradesh, India was monitored with obliquebanded leafroller (OBLR) and fruit tree leafroller (FTLR) pheromones over 3 seasons (1982-1984). The influence of trap design and their placement along vertical and horizontal gradients within the tree or outside it for standardizing monitoring procedures was determined.

Three traps, an indigenous developed delta trap, Farmoplant (Montedison, Italy) and Pherocon 1C (Zoecon Corp., USA) were found equally effective in trapping *A.pomivora*. More catches were obtained when traps were placed in the upper half of the tree canopy. This pattern remained similar in smaller (4.0m) and taller (7.0m) trees. Traps positioned at 5.3m (upper half) caught 27.07 and 56.89% more moths of *A.pomivora* than the traps at 3.5m (mid) and 1.7m (eye level), respectively. Traps positioned near the periphery attracted 36.75 and 51.61% more moths than the traps in the middle of the horizontal gradient and near the trunk, respectively. Most of the moths (95.8%) were captured within the tree canopy & 4.2% outside it.

COMPARISON OF PARASITOID COMPLEXES OF PHYLLONORYCTER SPECIES (LEPIDOPTERA: GRACILLARIIDAE) IN CONNECTICUT APPLE ORCHARDS. C.T. Maier, Department of Entomology, The Connecticut Agricultural Experiment Station, P.O. Box 1106, New Haven, Connecticut, U.S.A. 06504.

Parasitoid complexes of trivoltine apple leafminers, *Phyllonorycter* spp., were compared in 8 Connecticut apple orchards by analyzing percent of parasitism, species composition, and relative abundance during the first 2 leafminer generations of 1987. Percent of parasitized immature leafminers was greater in unsprayed than sprayed orchards. Parasitism increased from first to second generation in 3 unsprayed orchards, in 1 lightly-sprayed orchard, and in 2 of 4 heavily-sprayed orchards.

Fifteen of 17 (88%) parasitoid species obtained during the study were eulophids. The eulophid, *Sympiesis marylandensis* Girault, comprised the largest proportion of 11 of 16 (69%) samples. Unsprayed orchards had 9-12 parasitoid species per generation, and sprayed orchards had 1-9 species. Based on the Shannon-Weaver diversity index, the species diversity of parasitoids was higher in unsprayed than sprayed orchards.

Comparisons, based on Sorensen's quotient of similarity and on percent of similarity, indicated a low degree of similarity between parasitoid faunas of unsprayed orchards and those of sprayed orchards.

HOST PLANT RESISTANCE TO COCOA POD BORER. CONOPOMORPHA CRAMERELLA (SNELL.) (LEPIDOPTERA: GRACILLARIIDAE): MORTALITY OF THE FIRST LARVAL INSTARS WITHIN COCOA POD OF DIFFERENT CLONES.

I. Azhar*, MARDI, c/o Cocoa Research Station. P.O. Box 324. 91007 Tawau, Sabah, Malaysia; and G.E. Long, Department of Entomology, Washington State University, Pullman, Wa 99164-6432. USA.

Cocoa pod borer (CPB) is a serious pest of cocoa in the South East Asia. An investigation was carried out to determine the differential mortality of CPB first larval instars in cocoa pod of different clones. Ripe cocoa pods were peeled off and the penetration path of the first larval instars were traced and the points where they end were recorded. Hardness of the sclerotic layer (stony mesocarp) of each clone was also recorded using a penetrometer. First larval instars suffered greater mortality at the sclerotic layer (stony mesocarp) and inside the pod. Clones with harder sclerotic layer recorded higher percentage of mortality than those with soft sclerotic layer. Analysis of the sclerotic layer anatomy indicated that the cells were arranged in a compact manner with their cell walls sclerotized. The implications of the finding in the host plant resistance program are discussed.

MORTALITY BY NATURAL ENEMIES IN THE EUROPEAN CORN BORER OSTRINIA NUBILALIS (Hübner) (LEPIDOPTERA: PYRALIDAE) IN FIELD CORN. M. Coll* and D. G. Bottrell, Department of Entomology, University of Maryland, College Park, Maryland 20742, USA.

Two predators, *Orius insidiosus* and *Coleomegilla maculata*, and two parasitoids, *Lydella thompsoni* and *Macrocentrus* sp., are the most important natural enemies of the European corn borer (ECB) in Maryland. In the field, 57% of ECB eggs failed to hatch. Predation accounted for 30% of total egg mortality. Parasitization of larvae in five counties averaged 16% and 25% in the first and second generations, respectively. Of larval parasitization, *Macrocentrus* sp. accounted for 74% and 60% and *L. thompsoni* for 26% and 40% in the first and second generations, respectively. Mortality in ECB larvae in the stalks was lower (50%) than mortality in larvae in the ears (83%). Of total larval mortality, predation accounted for 36% in the stalk and 50% in the ears.

BIOLOGY OF THE APHIDOPHAGOUS PYRALID, CONOBATHRA APHIDIVORA (MEYRICK) (LEPIDOPTERA: PYRALIDAE). N. Arakaki Okinawa Prefectural Agricultural Experiment Station, 4-222 Sakiyama-cho, Naha 903, Japan

Up to present, only 2 species have been recorded as aphidophagous Phycitine in the world. One is the larvae of *Conobathra aphidivora* (Meyrick), the other is *Cryptoblabes aphidivora* Yoshiyasu and Ohara. In 1986, 2 aphidophagous pyralid larvae were found at Shuri, Naha, Okinawa: *Conobathra aphidivora* feeding on the sugar cane woolly aphid, *Ceratovacuna lanigera* (Zehntner) and *Cryptoblabes aphidivora* feeding on *Pseudoregma bambucicola* (Takahashi). The former is the first record in Japan. The results of crossing experiment between *Conobathra aphidivora* and *Cryptoblabes aphidivora* suggested that these two aphidophagous species are conspecific. The morphological and biological characteristics of *Cryptoblabes aphidivora* was identical with those of *Conobathra aphidivora*. Therefore, it is suggested that *Cryptoblabes aphidivora* is synonymous with *Conobathra aphidivora*.

Conobathra aphidivora plays an important role as natural enemy of the sugar cane woolly aphid. This species is widely distributed in the Ryukyu Islands and seems to be active throughout a year. The larvae construct silken runways in a large dense colony of aphids. The larvae sometimes appear outside the runways to catch the aphid preys.

INVESTIGATION OF THE DISTRIBUTION OF ELDANA SACCHARINA WALKER AND CHILO SP. (LEPIDOPTERA: PYRALIDAE) ON MAIZE. M.A. Botchey, Department of Zoology, University of Cape Coast, Ghana.

Different instars of Chilo partellus Swinhoe, Chilo zacconius Bleszynski and Eldana saccharina were found to concentrate their feeding activities on different parts of the plant at different physiological stages of the maize plant.

Anatomical studies of the maize stem indicated that at the nodes there is redistribution of water and nutrients by special radial parenchymatous cells which are directed to and end blindly at the cells separating the node and the axillary bud.

Fractions of various organic substances in the nodes and internodes at different physiological stages were related to the stem borer distribution on the plant.

THE POMEGRANATE MOTH, SPECTROBATES CERATONIAE (LEP. PYRALIDAE) IN IRAN.,

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Pomegranate is said to be native to Iran and accompanied by pistachio and palm date are economically important fruit exports. Plantation of Pomegranate trees is rapidly increasing, especially in Kavir margin area where the other fruit trees are not able to grow.

The pomegranate moth passes winter season as different larval stages and also as pupa, inside the infested fruits either falling on the ground or staying on the trees. The winter generation will appear in the beginning of spring, simultaneously with appearance of pomegranate buds. Majority of the winter generation, adults will emerge in the same time when the blossoms are going to be finished. They lay eggs on the dried histamines. After 5-6 days the eggs will hatch and the larvae move towards the flowers and feed from epicarp and grains of receptacle. After passing the whole larval stages, enter the staminal area through the same hole and change to the pupa. Each generation will last about 50 days and in climate situation of Iran, this insect has 3-4 generations. According to the life cycle this insect spends the whole winter inside the infested fruits as different larval stages and also pupae.

FRUIT FLY (*DACUS DORSALIS* HENDEL) INCIDENCE IN RELATION TO LOCATION OF PEACH, PEAR AND GUAVA ORCHARDS. G.S. Mann*, Department of Entomology, Punjab Agricultural University, Ludhiana, Punjab, India 141004.

For studying the influence of location on fruit fly incidence, isolated orchard (an orchard at least 2 km away from all types of orchards) and mixed orchard (an orchard located among the citrus, peach, pear, guava, mango, plum, loquat, *Jaman* & a few other types of fruit tree blocks) sites were selected and were observed for 2 crop seasons. In guava, fruit fly incidence was 32% and 90% along with 67 and 217 pupae/kg fruit in isolated and mixed orchards, respectively. The fly catches were 21 and 58 flies/trap in isolated and mixed guava orchards, respectively. In pear, 10% and 38% fly infestation along with 8 and 24 pupae/kg fruit were recorded in isolated and mixed orchards, respectively. The average fly catches were 4 and 65/trap in isolated and mixed pear orchards, respectively. In peaches, the fly incidence was 10% and 68% along with 4 and 111 pupae/kg fruit in isolated and mixed orchards, respectively. Thus, new orchard planting should be encouraged in isolated locations in fly infested areas.

Distribution and Abundance of *Dacus dorsalis* and *Dacus cucurbitae* (Diptera: Tephritidae) in a Typical Agricultural Area in Hawaii: Development of Large Scale Eradication Strategies. Roger I. Vargas, Tropical Fruit and Vegetable Research Laboratory, P. O. Box 2280, Honolulu, Hawaii, USA 96804.

Distinct distribution patterns for *Dacus dorsalis* Hendel and *Dacus cucurbitae* Coquillett were determined from trap and fruit infestation data. *D. dorsalis* occurred in moderate numbers in papaya orchards, but in very high numbers in surrounding areas infested with common and strawberry guava. *D. cucurbitae* was concentrated primarily in agricultural fields where cucurbits and tomatoes were planted and in very low numbers in surrounding vegetation. These findings have a significant effect on the choice of cultural controls, insecticides, bait sprays, and male annihilation for suppression/eradication. Results are discussed in the context of a large scale program to eradicate *D. dorsalis* and *D. cucurbitae* throughout the area to create a fruit fly infestation-free zone.

THE EFFECT OF TANNINS AND OF AMINO ACIDS UPON THE OLIVE FRUIT FLY, *DACUS OLEAE* Gmel (DIPTERA:TEPHRITIDAE). A.G. Manoukas, Institute of Biology, N.R.C. "Demokritos", Athens 153 10 Greece.

It has been shown that tannins form complexes with amino acids. This may be important for the nutrition of the olive fruit fly larvae which have a dietary requirement for free amino acids.

The effect of tannins, their breakdown products and of certain amino acids upon growth and development of the olive fruit fly larvae has been studied alone and in combination.

It was found that tannin was detrimental to the adult emergence at the level of 0.5 % of the diet while gallic acid one of its major breakdown products was detrimental at the level of 0.1%. Methionine, lysine and glycine affected larval growth and development at 0.1, 0.4 and 0.8%, respectively. Tannin at the level of 0.25 % modified the detrimental effect of methionine, lysine and glycine when included in the diet at the level of 0.1, 0.4 and 0.8%, respectively. The results will be presented and the interactions which may be involved will be discussed.

AGE-RELATED RESPONSE OF ADULT *DACUS DORSALIS* HENDEL TO METHYL EUGENOL AND ADULT *DACUS CUCURBITAE* COQUILLET TO CUELURE. Tim T. Y. Wong, Tropical Fruit and Vegetable Research Laboratory, U. S. Department of Agriculture, Agricultural Research Service, P. O. Box 2280, Honolulu, Hawaii 96804.

Field cage studies showed that newly emerged male *D. dorsalis* respond to methyl eugenol almost immediately and that response intensifies with age so that over 90% respond by the time they reach sexual maturity. Female response did not increase with age and fluctuated between 15-29% for the laboratory strain and 4-10% for the wild strain. In contrast, field cage studies showed that 50% or more male *D. cucurbitae* respond to cuelure after they reach sexual maturity. Females did not respond to cuelure at any age.

AGE RESPONSE OF *DACUS DORSALIS* HENDEL TO ATTRACTANT METHYL EUGENOL: AN IMPLICATION IN AGE-STRUCTURED POPULATION ESTIMATION. C.C. CHENG* AND W.Y. LEE, Institute of Zoology, Academia Sinica, Taipei 11529, Taiwan, R.O.C.

A major goal of population ecology is understanding the structure of population in terms of age, size and genotype. One such target is to estimate the field population of insect pests which, in view of monitoring age-structured population and the strategy of pest management, is very important. We report here that an attractant of *Dacus dorsalis*, which has shown to give some measure of attracting field population of *D. dorsalis*, confers, when was tested to various age cohorts. Although different age distributions have shown various attraction percentages in total population, there is no significant difference between the attraction percentages in the same age group. A weighted function for estimation the age-structured population of *D. dorsalis* has been proposed.

ERADICATION OF MELON FLY UTILIZING MASS TRAPPING. G.E. Loughner* and R.T. Cunningham, California Department of Food and Agriculture and United States Department of Agriculture respectfully.

The authors describe how a combination of McPhail and Jackson traps was used to eradicate an incipient urban infestation of *Dacus cucurbitae* in southern California. A highly modified trap density and placement protocol employing naled impregnated cue-lure wicks and an increased number of McPhail traps was used in the infested zone to achieve eradication.

EFFECT OF GAMMA-RADIATION ON SOME BIOLOGICAL ACTIVITIES OF THE MEDFLY *CERATITIS CAPITATA*. R.M.Abdu, A.M.Wakid*, and Eman S.M.El-Kholy. Department of Zoology, Faculty of Science, University of Qatar and Radiobiology Dept., Nuclear Research Centre, Atomic Energy Authority, Cairo, Egypt.

Fully grown pupae of *C.Capitata* were irradiated at 5, 7, and 9 Krad. Some biological activities of the emerged adults were studied. The results indicated that the mating activity was affected by the radiation dose. Frequency of mating of males was decreased with the increase of dose. Irradiated females with 9 Krad were more attracted by normal males than normal female. Effects on mortality, attraction to light, colour and odour of adults were also studied. All doses used have no effect on visual sense organs response in both males and females. Unirradiated females were more attracted to the green light than female irradiated at 9 Krad. Radiation showed no effects on response to Guava odour at high dose. All doses used had no effect on the mortality of the adult flies.

HIGH-TEMPERATURE FORCED-AIR QUARANTINE TREATMENTS FOR COMMODITIES SUBJECT TO INFESTATION BY THREE TEPHTRITID FRUIT FLY SPECIES IN HAWAII. J.W. Armstrong*, J.D. Hansen, and B.K.S. Hu. USDA-ARS, P.O. Box 4459, Hilo, Hawaii 96720 USA.

A high-temperature forced-air quarantine treatment was developed for Hawaii-grown 'Solo' papaya subject to infestation by Mediterranean fruit fly, *Ceratitidis capitata* (Wiedemann); melon fly, *Dacus cucurbitae* Coquillett; and oriental fruit fly, *D. dorsalis* Hendel. The treatment consisted of forcing hot air over papayas in four controlled incremental temperature stages. The beginning forced-air temperature stage was $43 \pm 1^\circ\text{C}$ for 2 h or until the fruit center temperature (FCT) reached $41 \pm 1.5^\circ\text{C}$, followed by $45 \pm 1^\circ\text{C}$ for 2 h or until the FCT reached $44 \pm 1^\circ\text{C}$, followed by $46.5 \pm 0.5^\circ\text{C}$ for 2 h or until the FCT reached $46.5 \pm 0.75^\circ\text{C}$, followed by $49 \pm 0.5^\circ\text{C}$ until the FCT reached 47.2°C . When the FCT reached 47.2°C , the treatment was complete and the fruits were immediately hydrocooled until the FCT was below 30°C to prevent heat damage to the papayas. This treatment was efficacious against the eggs, first instars and third instars of all three fruit fly species at the Probit 9 level of quarantine security.

A "quick run-up" modification of this treatment for papayas, and modifications of this treatment for other fruits subject to attack by these fruit flies are discussed.

MEDITERRANEAN FRUIT FLY MASS REARING FOR SIT APPLICATION: INCREASED UTILIZATION - COST REDUCTION OF LARVAL DIET. A.P. Economopoulos*, N.D. Bruzzone, V. Wornoyaporn, A.A.R. Al-Taweel, Hua-Song Wang, Entomology Unit, Joint FAO/IAEA Programme, Agency's Laboratories, Seibersdorf, IAEA, Wagramerstrasse 5, P.O. Box 100, A-1400 Vienna, Austria.

The standard Seibersdorf starter-finisher (1:19, w/w) larval diet has as follows: wheat bran 24.2, sugar 16.2, brewer's yeast 8.1, citric acid 1.2 in the starter or 0.6 in the finisher, sodium benzoate 0.5 and water 50.5%. The experimental goal was to: (a) substitute sugar and Schwegat brewer's yeast by materials easily found at low or no cost in potential Sterile Insect Technique application areas (e.g. Egypt for the present tests), (b) reduce the quantity of basic nutrients in the finisher diet, and (c) re-use the finisher diet following heat treatment (to kill remaining larvae or pupae). Molasses replaced sugar in the finisher bulk diet with practically no effect on larval production and insect quality (pupal size, adult emergence, flight ability), provided sugar was used in the starter. If molasses were used in both starter and finisher, then the larval production and adult emergence were reduced by 10-15% as compared to the Seibersdorf control diet. A very cheap yeast produced in Cairo was found to increase the diet larval production and insect quality by 5-10% when it replaced the Austrian Schwegat brewer's yeast. No substantial effect was observed on larval production and insect quality when molasses were reduced by 50% in the finisher diet. The same was true with yeast but only when molasses were increased simultaneously. The finisher diet could be used twice, provided, following heat treatment, water was added and the diet was mixed to proper texture and combined with fresh starter. The addition of a small quantity of sugar improved the flight ability of insects, while no obvious improvement resulted from similar additions of yeast, preservative or all three combined, or when used diet was mixed with fresh at 3:1 (w/w) and then combined with fresh starter.

COMPARISON OF THE GENOMIC LOCALIZATION OF HOMOLOGOUS GENES IN Tephritidae FLIES AND OTHER DIPTERA. A.R. Malacrida*, G. Gasperi, G.F. Biscaldi, L. Baruffi, R. Milani, Department of Animal Biology, University of Pavia, Pavia, Italy.

Twenty-four loci have now been assigned to four, out of the six, linkage groups of *Ceratitidis capitata*. They include: structural genes coding for enzymes functions, sex-ratio distorting factors, developmental proteins. From a large number of estimated recombination percentages, internally consistent linkage maps were constructed for these groups. These linkage informations have revealed inter-specific chromosome homologies with other Tephritidae flies (*Rhagoletis pomonella*, *R. completa*, *R. tabellaria*) and with unrelated species such as *Drosophila melanogaster* and *Musca domestica*. These results are discussed from an evolutionary point of view.

P-ELEMENT TRANSFORMATION OF THE MEDFLY, *CERATITIS CAPITATA*: PANACEA OR BUST? D. O. McInnis, S. Y. T. Tam, C. R. Grace, Tropical Fruit and Vegetable Research Laboratory, Honolulu, Hawaii; D. Haymer, University of Hawaii, Honolulu, Hawaii; A. K. Kumaran, L. Heilmann, J. Courtright, Marquette University, Milwaukee, Wisconsin.

Drosophila P-elements containing a bacterial gene for neomycin resistance coupled to a heat shock promoter have been injected into medfly embryos in the hope of inducing genomic transformation. To date (Jan. 88), over 20,000 Embryos have been injected with no evidence for transformation. Several lines have been isolated which demonstrated tolerance/resistance above control levels, but such tolerance was invariably lost after several generations. Transient expression of the P-element has been demonstrated in the injected (G_0) generation. Variations of the standard P-element microinjection are being attempted including the use of linear P-element DNA, post-injection irradiation, and coinjected *Drosophila* cytoplasm. In addition, other potential transformation vectors are being evaluated from *Drosophila*, while the medfly genome is searched for possible transposable elements.

DISTRIBUTION AND TRANSFORMATION OF MUSTARD APHID COUNTS. N.N. Singh* and V.N. Rai, Department of Entomology, Banaras Hindu University, Varanasi-221005, India.

The valid interpretation of observed data needs statistical analysis. But the direct analysis of the data which shows non-normality or inequality of variances may lead to inappropriate interpretation. The above difficulty can be overcome largely by transforming the data on suitable scale and analysing the transformed values. The nature of the transformation to be chosen depends on the probability distribution of the observed variable/variables. For population counts, two transformations are frequently used, namely, square root transformation and logarithmic transformation.

The distribution followed and the transformation to be used were examined for the data recorded on aphid population at various observational period during winter seasons of 1985-86 and 1986-87 on mustard crop. Normality of the transformed variable was tested by the Kolmogorov-test. Under present investigation it was found that the data followed log-normal distribution.

SOME ASPECTS OF THE BIOLOGY OF THE RUSSIAN WHEAT APHID *DIURAPHIS NOXIA* (MORDVILKO). ¹Y.K. Aalbersberg, ²M.C. van der Westhuizen, ¹F.C. du Toit and ²P.H. Hewitt*, ¹Small Grain Research Centre, Bethlehem, 9700 RSA and ²Department of Zoology and Entomology, University of the Orange Free State, Bloemfontein, 9301, RSA.

D. noxia alatae emigrate from the maturing wheat crop in November-December. *Bromus spp* which are widely occurring exotic grasses serve as the principal alternate hosts until the end of March. Thereafter volunteer wheat is colonized which then serves as the infestation source of the cultivated crop which emerges in May-June. The distribution of the infestation is initially random but thereafter contagious. The number of plants with symptoms can be used as a reliable estimate of the numbers actually infested. Infestations increase exponentially and attain their maxima at the flag-leaf stage. In severe cases all the plants may be infested. Early and late infestations caused yield losses of as much as 81% and 47% respectively.

Natural enemies showed functional responses to aphid populations but life-tables indicated that their effect was noticeable only when the numbers were on the decline. A border crop enhanced the numbers of natural enemies present but the impact on *D. noxia* numbers was minimal.

INFLUENCE OF FOOD QUALITY ON LIPID METABOLISM AND REPRODUCTION IN APHIDS.

Katrin Grüber, Department of Developmental Physiology, University of Tübingen, Morgenstelle 28, 7400 Tübingen 1, FRG

Lipids are important for insects as energy reserve and for reproduction. It has been argued that under unfavourable conditions aphids invest more in energy reserve than in offspring. *Metopolophium dirhodum* produced less offspring on a lush than on a flush plant. The lipid content of both test groups was determined relative to dry and fresh weight of the individuals. Both groups contained a similar relative fat content per fresh weight (9.8 % and 10.2%), but differed in their lipid content per dry weight (43% versus 38%). This suggests that under harsh conditions, *Metopolophium dirhodum* did not incorporate more lipids but less hydrophilic substances.

L4- larvae reared on a lush plant contained about 38% fat per dry weight. During starvation in the last instar the relative fat content decreased to 31 %. In this period mainly fat of the soma was metabolised. However, the lipid content of the gonads did not change significantly.

Adults of the cereal aphids *Metopolophium dirhodum* and *Sitobion avenae* had a similar fat content per dry weight (36% and 38%). This did not correspond to a similar tolerance to starvation. After six days, 60 % of adults of *Sitobion avenae* were alive but only 30% of *Metopolophium dirhodum*.

SEASONAL VARIATION IN PHOTOPERIODIC RESPONSE: EVIDENCE FOR LONG DISTANCE MOVEMENTS BY PEA APHID POPULATIONS. M.A.H. Smith and P.A. MacKay*, Department of Entomology, University of Manitoba, Winnipeg, Manitoba Canada R3T 2N2.

The purpose of the study was to quantify long distance movements in populations of pea aphid, *Acyrtosiphon pisum* (Harris), by estimating origins and distances travelled by immigrants into a southern Manitoba population. Previous experiments showed a strong relationship between latitude of origin and the photoperiods at which pea aphid populations are stimulated to produce the diapause stage. Therefore, the approach was to use photoperiodic response as a physiological marker to identify the source of immigrant aphids. We measured the responses of 89 clones from Glenlea, Manitoba (49° 38'N), sampled 5 times over 2 seasons. One sample of clones collected the first season had photoperiodic responses similar to those of a population nearly 400 km to the south, and significantly different from clones collected the previous spring at the same site. Weather analysis corroborates that the migrants were probably carried into Manitoba on a southerly flow of air during the previous 24 to 36 hours.

TEMPORAL ANALYSIS OF THE SPREAD OF VIRUSES IN MELON FIELDS AND ITS RELATION TO APHID LANDING RATE. S.J. Castle, Department of Entomology, University of California, Riverside, California 92521, USA.

Muskmelon fields at two sites in California, USA were monitored for virus incidence and aphid landing rate. A cohort of 100 plants at each site was sampled weekly throughout the season for virus incidence while aphid landing rate was estimated with a set of green tile water traps. Detection and identification of virus(es) in plants was achieved with ELISAs for two common cucurbit viruses, ZYMV and WMV-2.

Variation at the level of two to four orders of magnitude were seen in the total number of individuals of known vector species trapped from one season to the next. Differences in aphid numbers between sites was not so great; however, virus incidence varied significantly between location and seasons. The time at which primary infection within the fields were established with respect to the flight phenology of vector species was an important determinant of the rate of spread and total incidence of virus within a field.

A REVISION OF THE FORECASTING SCHEME FOR VIRUS YELLOWS IN SUGAR BEET IN THE U.K. A.M. Dewar,* Broom's Barn Experimental Station, Higham, Bury St Edmunds, Suffolk, U.K. and R. Harrington, Entomology & Nematology Department, Rothamsted Experimental Station, Harpenden, Herts., U.K.

New revised regional forecasts of virus yellows incidence in sugar beet in the U.K. have been devised using multiple regression analyses. Forecast equations include information on (1) the previous year's virus incidence, (2) the number of aphids, *Myzus persicae*, migrating in the autumn, (3) the severity of the winter weather and (4) the timing of spring migrations of *M.persicae* into the beet crop. Forecasts using the first three of these variables account for up to 66% of the variance in virus incidence and give growers the option of applying aphicidal granules at drilling to control the disease. Forecasts using all four variables account for up to 89% of the variance in virus incidence and can forewarn growers and the sugar industry of potential epidemics.

SYRPHIDS IN THE INTEGRATED PEST MANAGEMENT OF THE CABBAGE APHID, *Brevicoryne brassicae* (L.) IN THE INDIAN HIMALAYAS. O.P. Bhatta, Department of Entomology, Dr Y.S. Parmar University of Horticulture & Forestry, Solan, India.

The Cabbage Aphid, *Brevicoryne brassicae* (L.) is the limiting factor in the cultivation of cole crops in the Himalayan region of India. In 1980, a project was initiated to study the natural enemies of this aphid. Among the natural enemies, syrphids were found efficient in the suppression of this aphid population because of their voracity, better synchronization, and high rate of reproduction. During the investigation, nine syrphid species were identified and studied for constructing life tables. On the basis of reproductive capacity and generation survival, *Scaeva pyrastris* showed promise and could be relied upon for effective aphid control in cole crop ecosystems. It is intended to rear *S. pyrastris* artificially and release in the field for augmenting integrated pest management of *B. brassicae*.

Syrphid species were found to control the aphid on cole crops as well as aphids of other horticulturally important crops. Therefore, these studies are of interest and immense value to the horticulturists, in general. This project is scheduled to continue until the 1990 time frame.

BIOLOGICAL CONTROL OF APHIDS IN COMMERCIAL GREENHOUSES AND ORCHARDS USING THE PREDATORY MIDGE, *APHIDOLETES APHIDIMYZA* (DIPTERA: CECIDOMYIIDAE). L.A. Gilkeson, Applied Bio-Nomics Ltd., P.O. Box 2637, Sidney, British Columbia, Canada V8L 4C1.

Release rate experiments using *A. aphidimyza* to control *Myzus persicae* on sweet peppers were conducted in 2 commercial greenhouses in 1987. A total of 10 midges per plant per year (ca. 25¢ per plant), was sufficient to control aphids in both greenhouses. Suitability of the floor for pupation appeared to be an important factor in establishing predator populations. Low intensity light at night prevented predator larvae from diapausing in the greenhouse after mid-September.

In apple orchards, one release of midges in late May provided excellent control of *Aphis pomi* in blocks of 4-8 year old trees. Control was not acceptable in 1-year-old trees, probably because midges were blown out of the test area. Results of 1988 greenhouse and orchard trials will be reported.

CULTURAL PRACTICES TO REDUCE INFESTATIONS OF THE GREEN PEACH APHID, *MYZUS PERSICAE* (SULZER) (HOMOPTERA: APHIDIDAE) ON FLUE-CURED TOBACCO. P.J. Semtner, Virginia Polytechnic Institute and State University, Southern Piedmont Agricultural Experiment Station, P.O. Box 448, Blackstone, Virginia 23824.

The influence of flue-cured tobacco transplanting date and decapitation (topping) stage on green peach aphid populations was investigated between 1984 and 1987. Transplanting early in the recommended planting period (early May) gave significant reductions in aphid populations on tobacco in late July and August, when compared to populations on tobacco transplanted near middle of recommended planting period (mid-May). Topping in button stage resulted in reductions in aphid populations on tobacco during late July and early August, even after both treatments had been topped. Early topping of tobacco plants was not as effective in reducing aphid populations on tobacco transplanted near the end of the recommended planting period (late May). In a topping stage experiment tobacco topped in the button or elongate stage had significantly fewer aphid numbers during late July and early August than that topped in the early flower or full flower stages. The combination of early transplanting and early topping gave the greatest reduction in aphid populations and usually resulted in higher yield and quality.

SIGNIFICANCE OF SPRAY DEPOSIT QUALITY UPON THE LETHAL AND SUB-LETHAL EFFICACY OF BIFENTHRIN AGAINST APHID PESTS OF CHRYSANTHEMUMS. A.J. Adams and F.R. Hall, Department of Entomology, Ohio State University, Ohio Agricultural Research and Development Center, Wooster, OH 44691, U.S.A.

Droplets of uniform size, containing bifenthrin (25% e.c.), were applied to sections of chrysanthemum leaves at a pre-determined density (droplets/cm²). Aphids were placed on the treated surface and sub-lethal effects of the deposit were investigated using video-analysis. Behavioral responses were quantified as distance moved during exposure and number of insects walking or dropping off the leaf. These data were examined in relation to the likelihood and frequency of encounter with bifenthrin deposits and the consequent acquisition of the toxicant. In addition, the response of aphids was monitored when the insecticide was applied to pre-infested leaf sections. An optimal sub-lethal effect (walking distance) occurred in response to a 40-fold range in quantity (0.64-28.63 ng/cm²). The efficiency of bifenthrin utilization increased with decreasing concentration (7.5 g a.i./l to 0.0075 g a.i./l) and decreasing droplet size (Vmd 160 µm to 60 µm). The LN₅₀ (drops/cm² causing 50% mortality) occurred at droplet densities 2-10 times greater than for the corresponding optimal walking response.

INHERITANCE OF RESISTANCE IN TWO WHEAT LINES TO THE RUSSIAN WHEAT APHID, *DIURAPHIS NOXIA* (HOMOPTERA: APHIDIDAE). F. du Toit, Grain Crops Research Institute, Small Grain Centre, Private Bag X29, Bethlehem, 9700, Republic of South Africa.

Studies were conducted to determine the inheritance of resistance to *Diuraphis noxia* (Mordvilko) in two wheat (*Triticum aestivum* L.) lines, PI 137739 and PI 262660 and to establish whether resistance in these lines was governed by the same or different genes. Resistance reactions of seedlings involving resistant x susceptible and resistant x resistant hybrids were evaluated in the greenhouse. The F₁ plants in all the crosses were resistant and back-cross populations involving susceptible parents resulted in a ratio of 1 resistant : 1 susceptible. The F₂ plants from resistant x susceptible crosses segregated into the ratio of 3 resistant : 1 susceptible. The F₃ families generated from randomly selected F₂ seeds segregated into the ratio of 1 resistant : 2 segregating : 1 susceptible. F₂ plants from PI 137739 x PI 262660 crosses segregated into a 15 resistant : 1 susceptible ratio. The segregating patterns obtained, indicated that resistance in each line is controlled by a single dominant gene and that these two genes are inherited independently.

INSECTICIDE RESISTANT DAMSON-HOP APHID IS THE KEY PEST OF HOPS IN EUROPE: HOW TO COPE WITH IT? I. Hrdý, J. Jelena Kuldová and Z. Wimmer, Institute of Organic Chemistry and Biochemistry, Czechoslovak Academy of Sciences, U Šalamounky 41, 158 00 Praha 5, Czechoslovakia

Outbreak of the damson-hop aphid, *Phorodon humuli* in the Czech hop growing area in 1967 was caused by thiometon resistance. Since that the hop aphid became cross resistant to a wide spectrum of organophosphate and carbamate insecticides, some of which were never used in practice. The RF for thiometon increased and remained at a high level, although the use of this insecticide was discontinued. Resistance to other OP and carbamate insecticides increased and remained also stable. Differences in resistance spectra of the hop aphid from Czech and Bavarian hop gardens and spreading of resistant biotypes in Czechoslovakia are described. By permanent use of pesticides, predators and parasites in hop gardens were substantially reduced. The present tactics of the hop aphid control should be revised. In laboratory screenings and preliminary field trials promising juvenile hormone analogues were found.

IMPACT OF VEGETATION AND PREY DIVERSITY ON APHIDOPHAGOUS SUBGUILD ORGANIZATION. F.Szentkirályi, Department of Zoology, Plant Protection Institute of the Hungarian Academy of Sciences, H-1525 Budapest, P.O.Box 102, Hungary.

The organization of two neuropteroid groups /Chrysopidae, Hemerobiidae/ was studied in continuous maize monocultures and crop rotation fields between 1978-1985. Chrysopids and hemerobiids formed two aphidophagous subguilds according to their spatio-temporal and food separation. Seasonally repeating patterns of aphid species occurrences were found in maize stands and adjacent herbaceous vegetation which determined the activity patterns of the subguilds. The more diverse adjacent vegetation supported more diverse aphid assemblages and the neuropteroid groups had higher species diversity in such areas. The absence of shrub and tree foliage in the surroundings drastically reduced the species richness of the subguilds.

THE EFFECT OF SOME INSECT PREDATORS, PARASITES, AIR TEMPERATURE AND HUMIDITY ON POPULATION FLUCTUATIONS OF ALFALFA APHIDS IN KARAJ, IRAN. Gh. Reza Rassoullan, Plant Protection Department, Agricultural College, University of Tehran, Karaj.

The green pea aphid can be observed throughout the growing season particularly from late May to mid June under Karaj climatic conditions. During this period, the mean monthly maximum temperature was about 28°C and the relative humidity was about 60-65 percent. These insects overwinter as nymphs and viviparous females. Sexual forms and eggs could not be seen under field conditions. The spotted alfalfa aphid, *Therioaphis trifolii* forma *maculata* was most prevalent in summer, when the mean monthly maximum temperature was about 33-34°C and the relative humidity was around 44-58 percent. These aphids also overwintered as nymphs and viviparous females in the field. In order to investigate the effect of biotic and abiotic factors on aphid population, weekly data on five variables (number of aphids, number of parasites, number of predators, maximum air temperature and relative humidity) were statistically analyzed. As the results show, the predators proved to be most effective, whereas abiotic factors played a secondary role under field conditions.

INTEGRATED FARMING SYSTEMS FOR PEST MANAGEMENT.

Clive A. Edwards, Entomology Department, Ohio State University, Columbus, Ohio.

Integrated pest management has involved decreased use of pesticides combined with the use of alternative, ecologically desirable tactics for suppressing pest populations. However many of the current trends in agriculture, aimed at maximizing yields, have tended to increase pest and disease problems. These include monoculture, the use of crop varieties which respond to high inputs of fertilizers, maximal weed control and extensive cultivations for seed bed preparation. All these activities can impact unfavorably upon the incidence of pests and diseases. It is essential to consider interactions between the effects of: crop protection measures, fertilizers, rotations and cultivations as key issues in controlling pests and diseases. To do this, it is proposed to use "An integrated farming system (IFS) for pest management, with the maintenance or increase in the income of the farmer as a central aim, but decreasing inputs of non-renewable fossil fuel-based resources, improving cultural and biological inputs and integrating the effects of all these inputs to control pests and diseases, with minimal environmental, ecological and sociological impacts". Practical examples of such systems are described.

ULTRA SMALL AND CONVENTIONAL DROP PESTICIDE APPLICATION WITH A DRIFT CONTROLLED SPRAYER. R.B. Rogers*, L. Bugeaud, Rogers Engineering Inc., 240-103rd St., Saskatoon, SK, Canada S7N 1X7

This study compared the deposit efficiency of ultra small drops (130 μ m VMD) and conventional drops (410 μ m VMD) on small plants in a chem fallow field. A Windfoil plot sprayer, manufactured by Innovative Equipment Inc. Saskatoon, Canada was pulled by an ATV. The plot sprayer equipped with 800017TC tips (500 mesh screens) and 80015SS tips (100 mesh screens) applied pesticides with 10 to 100 L/ha of carrier. The small drops were applied with volumes as low as 2.6 L/ha, the large drops with volumes up to 100 L/ha. Evaluations were done at three speeds - 8, 12 and 15 km/h, and at three nozzle angles - 30° ahead, vertically down and 30° backwards. Paper test strips were used to confirm sprayer application evenness. The plants were sprayed with a mixture of pesticide formulation and sodium fluorescein dye as a tracer.

The ultra small drops deposited 1.9% of the spray solution sprayed on the plants while the conventional drops deposited .4% (LSD .6 at the 1% level). The increase attributable to the small drop application is 4.75 times that of the large drops. Small drops sprayed vertically and ahead deposited (70%) on the strips, 1.3 times that deposited by large drops (54%) in the same positions (LSD 8.4% at the 5% level). Increasing speed from 8 to 25 km/h decreased deposits on paper strips with large drops, whereas small drops maintained their deposit efficiency. On plants, there was no significant effect of speed for either drop size. On paper strip, the vertical nozzle angle increased deposit over the forward and backward angles with ultra small drops, but not with large drops. On plants, there were no significant differences. The above differences indicate that actual plants are vastly different spray collectors than paper strips.

This study was funded by the Western Grain Canadian Wheat Growers' Association and the Western Grains Research Foundation.

TIMING OF CONTROL BASED ON THE STAGE STRUCTURE OF PEST POPULATIONS: A SIMULATION APPROACH. Hsin Chi, Department of Entomology, National Chung Hsing University, Taichung, Taiwan, Republic of China.

Since the susceptibility of pest to control agents varies among stages, knowledge of the stage structure of a pest population is critical for implementation of control strategies. However, computer simulations based on traditional female age-specific life tables are inadequate in this respect. On the other hand, a computer simulation of population growth based on an age-stage two sex life table reveals the stage structure of a pest population at any time period. Using this model, the most economical and efficient control strategies can be chosen and applied at the appropriate times. This stage structure oriented concept of pest management will play an important role in the future.

FOREIGN EXPLORATION FOR PREDATORS: A PROPOSED NEW

METHODOLOGY USING MONOCLONAL ANTIBODIES IN ELISA. M.H. Greenstone, Biological Control of Insects Research Laboratory, U.S. Department of Agriculture, Columbia, Missouri 65205, U.S.A.

Introductions of exotic predators have been attempted much less often than introductions of exotic parasitoids. This may be partly because of controversy over attributes of the "ideal" natural enemy. A more fundamental obstacle has been the lack of a methodology for identifying any but the most prey species-specific predators of target pests. I propose a new methodology, employing on-the-spot serological analysis of predators. The feasibility of this approach is demonstrated with data from monoclonal antibody based enzyme-linked immunosorbent assays (ELISA) of predators fed larvae of species of the Corn Earworm Complex.

PARASITOID PREFERENCE FOR MONOCULTURE PLANTINGS.

R.B. Smith, Department of Plant Science, Ste.248, 2357 Main Mall, University of British Columbia, Vancouver, British Columbia, Canada, V6T 2A2.

A factorial experiment was conducted to simultaneously test the effects of host plant concentration (i.e. monocultures and dicultures) and generalist predator numbers on the densities of four species of lepidopteran pests. Neither predator numbers nor planting treatments alone affected population densities of the caterpillars. However, there was significantly greater parasitism in the monocultures than the dicultures by the Tachinid, *Voria ruralis*, on *Autographica californica*, and by the Ichneumonid *Diadegma insulare* on *Plutella xylostella*. Predator density did not affect parasitism by either parasitoid.

These data support the notion that resource concentration is an important regulating factor in pest population dynamics. However, in this case herbivore movement does not explain the phenomenon, but rather parasitoid behaviour does. It is suggested that parasitoids are attracted by olfactory cues to the more concentrated host plant resource.

THE ASSOCIATION BETWEEN CLIMATE AND ESTABLISHMENT IN

BIOLOGICAL CONTROL OF WEEDS. R. Leen, Div. of Biological Control, University of California, 1050 San Pablo Avenue, Albany, CA. 94706 USA.

The influence of climate on success and establishment of biological control agents has been reported in several instances. However, the prevalence of this climatic influence has yet to be substantiated.

Over 40 years of import and release records of the USDA, Biological Control of Weeds Laboratory, Albany, CA., subsequent evaluation reports and climatic data were compiled and examined for evidence of climatic influence on establishment of agents introduced for biological control of weeds.

BIOLOGICAL CONTROL OF TANSY RAGWORT *Senecio jacobaea* L. IN WESTERN OREGON. E.M. Coombs*, P.B. McEvoy, and G.S. Cox. Oregon Department of Agriculture, Salem, and Oregon State University, Corvallis, USA.

Three insects have been intensively managed for the biological control of ragwort *Senecio jacobaea* in Oregon since 1975. The Oregon Department of Agriculture has made 2961 releases of ragwort flea beetles *Longitarsus jacobaeae* (Waterhouse), 3624 of cinnabar moths *Tyria jacobaeae* L., and 206 of ragwort seed flies *Hylemyia seneciella* (Meade). Ragwort infestations in 17 counties in western Oregon, 300,000+ km², have been reduced by an estimated 70%. Annual estimates of density have been made on 41 sites which span the topographic, climatic, and land use variation in the region. Data from 13 sites indicated a 98% reduction in ragwort flowering plant density after five years (7.5±0.8 plants/m² to 0.1±0.08 plants/m²). On six sites monitored for ten years after flea beetle introduction, mature ragwort has disappeared. Control is attributed primarily to the flea beetle, and secondarily to the cinnabar moth and seed fly. Nine of ten sites sampled for buried ragwort seed contained seed (range: 25-3200 seeds per m²). Since buried seed creates a potential for resurgence, continued monitoring and redistribution of agents is necessary to maintain control of tansy ragwort.

INSECT ANTIFEEDANT ACTIVITY OF CERTAIN SYNTHETIC FLAVONOIDS AND THEIR RELATED NATURAL COMPOUNDS.

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Different oxygen heterocyclic compounds viz., flavan-4-ols, flavones, flavonones coumarins and some natural compounds isolated from *Premna tomentosa* Willd. (Verbenaceae) were tested for their antifeedant activity against IIIrd instar larvae of *Spodoptera litura* F. Among 27 compounds tested, 11 compounds showed very promising antifeedant activity at 1000 ppm by non-choice method. The present investigation reveals that the chloro substituted compounds were found to be more active than the non-chloro compounds. Methoxyl group compounds also showed high antifeedant activity, with the increase in the number of methoxyls the antifeedant activity was also increased.

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BIOLOGICAL CONTROL AND INSECT-INDUCED YELLOWING OF LEAVES OF *CHROMOLAENA ODORATA* (L.) K&R. (Asteraceae). R. Muniappan* and Mari Marutani, Agricultural Experiment Station, University of Guam, Mangilao, Guam 96923, U.S.A.

Pareuchaetes pseudoinsulata Rego Barros (Lepidoptera; Arctiidae) was introduced and established on Guam in 1985 for control of *Chromolaena odorata*. Since then, *P. pseudoinsulata* has effectively suppressed *C. odorata*.

The feeding of *P. pseudoinsulata* caterpillars on *C. odorata* caused yellowing of leaves. Artificial defoliation of the plant did not produce the same effect as the insect. Breaking tensile strength of yellow leaves from the insect infested plant was higher than one of green leaves from the uninfested plant. A preliminary chromatographic observation revealed a distinct difference in the presence of phenolic compounds between yellow and green leaves. Yellow and green leaves were also compared for electrophoretic properties.

Growth of caterpillars of *P. pseudoinsulata* were compared by feeding green and yellow leaves of *C. odorata*. Caterpillars fed on yellow leaves had a higher mortality and a slower growth rate. When both green and yellow leaves were fed at the same time, larva favored green leaves.

INSECT PESTS ON *AZOLLA*, AQUATIC FERNS FIXING N FROM AIR, IN ASIA. O. Mochida, Tropical Agriculture Research Centre, Ibaraki-ken, Tukuba-si, Oowasi, 305 Japan.

Azolla spp., nitrogen-fixing aquatic ferns, are important for rice and other crop production as green manure and also used as feeds for fish and other domestic animals such as ducks, chickens, pigs, etc. in Asia. There are 4 keys involved in *Azolla* growth for farmers' use; presence of water, high phosphate content in water, pests, and typhoon/flood in southeast Asia, other than the price of chemical N-fertilizers.

In the world, pests are divided into 3 groups; Insecta, Arachnoidea and Mollusca. About 30 species of insects and about 10 species of snails were recorded as pests in the world, whereas 2 species of water-mites were reported in S. America.

Among insects, Chironomids are the largest group in number of species; 13 species. Pyralid moths are the 2nd largest; 6 including the most serious pest, *Ephestiopsis vishnu*, and the 2nd most serious pest group, *Elophila* spp., in the southeast Asia. Five species of Curculionids were collected in Asia by December 1986.

Yield loss of standing plus harvested biomass was an average of 74.4 and 57.1 % in *A. microphylla* and 66.4 and 44.8 % in *A. pinnata imbricata* in 1985 and 1986, respectively, when tested at IRRI, Los Banos, Philippines.

PRELIMINARY REPORT ON THE PESTS OF *EURYALE FEROX* SALISB. IN NORTH BIHAR. R.K.Mishra*1 and V.Jha2 1. University deptt. of Zoology, L.N.Mithila Univ., Darbhanga. 2. Deptt. of Botany, C.M.Sc. College, Darbhanga, India-846004.

Euryale ferox Salisb. is the major aquatic cash crop of North Bihar. Preliminary observations on the crop have shown the attack of a number of insect pests during different parts of the year. Tender leaves of the plant are infested during Feb.-March by the leaf-rolling larvae of *Nymphula crisonalis* Walker. while its mature fibrous roots emanating out of the rhizome witness a tenacious attachment of the brown pupae of *Donacia* spp. during April-Aug. In addition, blood-red larvae of a stem-borer were found to inhabit the aerenchymatous tissues of its prominent ventral ribs. Numerous galls on its petioles and leaves are a common sight during July-Oct. Paper discusses the nature and extent of damage caused by these pests.

PEST MANAGEMENT IN COASTAL SWAMP FOOD CROP GROWING IN SOUTH SUMATRA, INDONESIA. J. Soejitno, Rochman, M. Iman*, J. van Lidth de Jude. Bogor Research Institute for Food Crops (BORIF), Jalan Cimanggu Kecil 2, Bogor, Indonesia.

Pest population studies were undertaken and farmers' control measures were monitored in the area of Karang Agung, near Palembang. Brown planthoppers (BPH), *Nilaparvata lugens* Stal, Stemborers, *Triporiza incertulas* Linn. and two rodent species, *Rattus argentiventer* and *Rattus exulans* are the major pests in rice. Integrated pest management is widely utilized. Cropping of resistant rice varieties, simultaneous planting, crop and varietal rotation and judicious use of insecticides are practices executed by farmers for BPH control. Stem-borer control was accomplished by simultaneous planting and insecticide application. Successful rat control was achieved through the integration of simultaneous planting, sanitation, regular organized mass hunting and use of rodenticides. In soybean plants the major pests are the podborer, *Etiella zinckenella* Tr., and the pod suckers, *Riptortus linearis* F. and *Nezara viridula* L. Insecticides are commonly used for controlling these pests. Ecological data indicate that the right time for the application of insecticides is one week after planting.

INTEGRATED PEST MANAGEMENT ON INSECT PESTS OF CEREALS: PROGRESS AND PERSPECTIVE IN INDIA. R.C. Joshi*, and N.C. Joshi, Department of Entomology, University of the Philippines at Los Banos, College, Laguna, Philippines, 3720.

The magnitude of damage due to insect pests of cereals is well documented, especially after the introduction of high yielding varietal programme in the country. Earlier insecticide recommendations (1955 to 1976) suggested spraying all crops with insecticide, as a routine form of crop insurance against insect damage irrespective of whether insects are present or not. This seemed attractive to farmers, but sole reliance on single component control created problems of residue, pollution, insecticide-induced-pest resurgence and insecticide resistance.

An account of the work done in India on pest management is presented highlighting favourable factors of its success in future and pointing constraints in its implementation on a wider scale. Change in the orientation of future research capitalizing on natural enemies, minimizing the use of modern conventional insecticides, as a crop protection measure to maximize crop yields at low level of management and reduce the cost of cultivation for the resource-scarce-farmers is discussed.

ENTOMOLOGY IN WEST ASIA AND NORTH AFRICA: A SUB-REGIONAL APPROACH. R.H. Miller, Cereal Improvement Program, International Center for Agricultural Research in the Dry Areas (ICARDA), P.O. Box 5466, Aleppo, Syria.

ICARDA has adopted a subregional approach to resolving the major insect pest problems of West Asia and North Africa. Cooperative networks between national program scientists and ICARDA scientists concentrate on entomological problems unique to that subregion. Such networks allocate more leadership and responsibility to national program scientists and allow ICARDA to play an important catalytic role in bringing scientists together, providing direction to research, and insuring the transfer of technological developments to the farmer.

Cooperative networks have been or are being established in the Nile Valley for aphids, in the Maghreb region of North Africa for Hessian fly, in the eastern Mediterranean countries for wheat stem sawfly, and in West Asia for suni bugs. Insect resistant germplasm has been identified by the aphid and sawfly networks which is currently being tested in several locations in different countries.

MANIPULATION OF THE LEAF-CUTTING ANTS THROUGH THE USE OF ALLELOCHEMICALS. I. SELECTION OF THE SOURCES OF ACTIVITY. F.J.M. Sales* and P.E. Howse, Federal University of Ceará, C.P. 3038, 60000 Fortaleza, CE, Brazil and The University of Southampton, Building 19, Southampton SO9 5NH, England.

Agricultural activities in the Neotropics leading to simplification of the ecosystems, have enhanced *Atta* spp. activity and turned land exploitation nearly unprofitable. The pertinent literature disclosed new ecological relationships of these species with the environment suggesting a compulsory shift in management strategy. Reactions of the leaf-cutting ant, *Atta sexdens rubropilosa* Forel, 1908 (Hymenoptera: Formicidae) to natural sources of allelochemicals have been investigated. A linear hypothesis model in a randomized block design of a factorial experiment was utilized to assess the response of the ants to the treatment combinations. When flower and leaves of the plant species were offered, simultaneously, to the workers, they exhibited a consistent preference for the flowers. From the treatments assigned, 93.64% of the material brought to the nest comprised flower fragments, 6.20% leaves, 0.04% orange mesocarp and 0.12% endocarp. Deterrent effects, on feeding, were observed in leaves of *Scilla* spp. and the ants were stimulated to explore, cut and transport to the fungus gardens the highly attractive flowers of *Mahonia aquifolium*.

EFFECTIVENESS OF AN IMPROVED TREATMENT OF PRUNED TWIGS IN THE BIOLOGICAL CONTROL OF *DRYOCOSMUS KURIPHILUS* (HYMENOPTERA: CYNIPIDAE). Y. Murakami, Faculty of Agriculture, Kyushu University, Fukuoka 812, Japan.

Pruning twigs in winter is one of the useful control methods to some degrees against *D. kuriphilus* accidentally introduced from China. Withered galls on twigs pruned, however, harbor overwintering larvae and pupae of the native parasitoid *Torymus* (*Syntomaspis*) *beneficus* and *T. (S.) sinensis*. Therefore, the removal of the twigs from orchards may have an adverse effect on the parasitoid populations. An experiment was conducted in a chestnut orchard where *T. (S.) sinensis* had been released in order to examine the effect on the parasitoid populations. Although the effect was not conclusive in the first year, significantly higher rates of parasitization and host-feeding by the parasitoids were realized in the second year in the plot where pruned twigs were gathered at the base of each tree and left there until the parasitoids emerged in the next spring from withered galls on twigs.

BEHAVIOURAL RESPONSES OF A PRIMARY PARASITOID *PRAPON PEQUODORUM* VIERECK (HYMENOPTERA: APHIDIIDAE) AND A SECONDARY PARASITOID *DENDROCERUS CARPENTERI* (KIEFFER) (HYMENOPTERA: MEGASPILIDAE) TO APHID HONEYDEW. D.E. Hood-Henderson*, Resource Ecology, University of British Columbia, Vancouver, Canada V6T 1W5 and A.R. Forbes, Agriculture Canada Research Stn. 6660 NW Marine Dr. Vancouver, Canada V6T 1X2.

Mated males and females of *Prapon pequodorum* Viereck and *Dendrocerus carpenteri* (Kieffer) were presented with patches of fresh aphid honeydew (HD) in a petri dish arena. Female primary parasitoids which had no experience with HD displayed behaviour unique to the patch area. Upon contact with the patch, their rate of travel slowed, and their degree of turning increased. Recognition of the stimulus appeared to depend on contact. Inexperienced secondary females responded similarly within the patch, but in addition behaved as though they detected HD odour before actual contact. Experienced females of both species also responded to HD, but not to such a marked degree as the inexperienced females. Habituation occurred in all groups. Males of both species whether experienced or not, habituated sooner than females and showed some erratic behaviour while in contact with the patch. Females as well as males behaved less predictably on HD that was 24 hours old.

FIRST RECORD OF PARASITOID OF *SCAPHOIDEUS TITANUS* BALL (RHYNCHOTA AUCHENORRHYNCHA). PRELIMINARY NOTE. A. Arzone, Institute of agricultural Entomology, Turin University, Italy.

The Nearctic leafhopper *Scaphoideus titanus* has been reported in Europe since 1960, where it now results to be diffused along the 45th parallel, in a narrow belt extending from the Atlantic coasts of France, across North Italy and Switzerland, up to Yugoslavia. Both in Europe and in North America, *S. titanus* appeared to be linked to grapevine in all its instars. In France and Italy, it is accused to transmit to grapevine the MLO of Golden flavesence. Until now, its epidemiology was entirely unknown not only in the Palaearctic Region but also in the Nearctic one. Investigations, that were carried out in northwestern Italy, put in light six Hymenoptera parasitoids: two Mymaridae, one Trichogrammatidae, and one Aphelinidae on the eggs and two Dryinidae on the nymphs. The researches on this subject are in progress with the aim to ascertain the parasitization rate of the six above species. By now, it is already possible to affirm that these parasitoids together with some predators, among which Miridae, Chrysopidae, and Araneae, are able to keep the populations of this leafhopper under the threshold of dangerousness.

A COMPARISON OF *APHYTIS YANONENSIS* AND *COCCOBIUS FULVUS* (HYMENOPTERA: APHELINIDAE): COMPLEMENTARY NATURAL ENEMIES IN A SUCCESSFUL BIOLOGICAL CONTROL OF *UNASPIS YANONENSIS* (HEMIPTERA: DIASPIDIDAE) IN JAPAN. M. Takagi* and T. Ogata, Institute of Biological Control, Faculty of Agriculture, Kyushu University, Fukuoka 812, Japan.

In 1980, two species of parasitoids, *Aphytis yanonensis* and *Coccobius fulvus* were introduced into Japan for the biological control of *Unaspis yanonensis* which had been one of the most serious pests of citrus in Japan. We compared biology and habits of them to choose release tactics: multiple- or single-species release. *Aphytis* is higher in the capacity for increase (r_0) than *Coccobius* because the former has a shorter generation time and is a thelytokous species. Therefore, *Aphytis* is expected to control a severe outbreak of the scale more easily. On the other hand, fecundity and longevity of *Coccobius* are higher and longer than those of *Aphytis*. Moreover, *Coccobius* attacks palatably the mature female adult of the scale which is more stable in seasonal population fluctuation at citrus groves than the immature adults, the main host of *Aphytis*. These indicate that *Coccobius* is a better agent to maintain the scale population at low level. Thus, we support multiple-species release in this case because two parasitoids can be complementary to each other on different levels of the pest population.

HOST STAGE SELECTION AND SEX ALLOCATION IN TWO COMPETING PARASITOID SPECIES (*LEPTOMASTIX DACTYLOPII* AND *LEPTOMASTIDEA ABNORMIS*) OF THE CITRUS MEALYBUG (*PLANOCOCCUS CITRI*). J.J.M. van Alphen, P.W. de Jong and A.W.M. Eijs, Department of Population Biology, University of Leiden, P.O. Box 9516, 2300 RA Leiden, The Netherlands.

The encyrtid parasitoids *Leptomastix dactylopii* and *Leptomastidea abnormis* are often simultaneously used for biological control of the citrus mealybug. To understand competition and coexistence we studied host stage selection and sex allocation in both parasitoids. *L. dactylopii* prefers 4th instars and produces the largest proportion of females in this stage. *L. abnormis* prefers 3rd instars and produces the largest proportion of females in this host species. *L. dactylopii* does not lay fertilized eggs in 2nd instars, whereas *L. abnormis* fertilizes 50% of the eggs laid in 2nd instars.

MICROCLIMATES AND ITS AFFECT ON HOST AND INDIVIDUAL DEVELOPMENT OF PUPAL PARASITES, *SPALANGIA ENDIUS* AND *NASONIA VITRIPENNESE*. Xue Ruide, Shanxi Medical College, Taiyuan, Shanxi, China.

Definition of microclimates and its affect on the host and individual development of pupal parasites, *N. vitripennese* and *S. endius* are presented. The relationship of the host and parasite, and affect on each other was studied with reference to mass production and release.

WHY DOES THE NUMBER OF TERATOCYTES IN THE BODY CAVITY OF *PIERIS* HOST PARASITIZED BY *APANTELES GLOMERATUS* L. DECREASE? T. Arakawa* and H. Kitano, Department of Biology, Tokyo Gakugei University, Koganei-shi, Tokyo 184, Japan

Teratocytes of gregarious parasitoid *Apanteles glomeratus* L. originate from its embryonic serosa and are released into the haemocoel of their host *Pieris rapae crucivora* larva when their eggs hatch.

It was reported by Hashimoto and Kitano (1971) that the number of teratocytes floating in the haemolymph of *Pieris* parasitized by *Apanteles* has been decreased to two-thirds at emergence of parasitoid larvae out of their host, compared with that when the first instar parasitoid larvae are still in their host. We observed some teratocytes in the guts of parasitoid larvae in the second instar. From this observation it is suggested that the decrease in the number of teratocytes in the haemolymph of *Pieris* is partly due to the parasitoid larvae feeding on them.

DISCRIMINATION BETWEEN PARASITIZED AND HEALTHY HOSTS BY *MICROPLITIS RUFIVENTRIS* KOK. E.M. Hegazi*, M.A. Shaaban, N.El-Singaby and R. Saleh. Department of Plant Protection, Faculty of Agriculture, Alexandria University, Egypt.

The response of mated female of *Microplitis rufiventris* Kok. to healthy and previously-parasitized *Spodoptera littoralis* (Boisd.) larvae was studied. Hosts possessed newly-laid parasite eggs were superparasitized while the healthy ones were less attractive for the parasite female. The latter showed strong rejection towards parasitized hosts possessing late first instar or other larval instars of the parasite.

MASS REARING AND INUNDATIVE RELEASES OF *DIACHASMI-MORPHA (BIOSTERES) LONGICAUDATA* (ASHMEAD) (HYMENOPTERA: BRACONIDAE) FOR SUPPRESSION OF THE *ANASTREPHA* FRUIT FLY COMPLEX. Dieter Enkerlin,*, Jorge Guillén, Tim Wong and Jorge L. Cancino. Inst. Tec. Monterrey, USDA/APHIS and ARS, Programa Moscamed, SARH/México.

According to Knipling (1986) in his model, augmentation releases of fruit fly parasites may be an alternative to large scale insecticide applications to reduce fruit flies substantially. If this can be proven in the field, it would be a major brake through in integrated pest management and/or eradication of fruit flies. In Tapachula, Chis. a small laboratory was established in July 1986, but with much more support in 1987. Mass rearing of *D. longicaudata* on *Anastrepha ludens* (Loew) has been successful. During July 1987 weekly inundative releases of this parasitoid were initiated in Mazapa de Madero, a narrow valley with only about 100 ha. of different fruit fly hosts and several important species of the *Anastrepha* complex. To measure results infested fruit is being collected, trap catches of flies are monitored and "sausages" containing third instar larvae, are hanged on host trees in the release and check area.

Results are very promising with up to 90% parasitism. Complete data will be shown, after about one year of parasitoid releases.

TESTING OF INSECT PARASITIC RHABDITID NEMATODES AGAINST *ARGE BERBERIDIS* LARVAE (HYMENOPTERA: ARGIDAE). J. Jarosz and M. Andrejko, Unit of Insect Pathology, Maria Curie-Skłodowska University, 20-033 Lublin, Poland.

Since entomogenous nematodes are potentially useful as biocontrol agents for the insect pests, an examination of the effect of *Neoplectana carpocapsae* (N.c.), *N. bibionis* (N.b.) and *Heterorhabditis bacteriophora* (H.b.) on *Arge berberidis* was undertaken using simulated natural systems. Larvae of *Arge* were found to be highly susceptible to infection by the rhabditid nematodes, especially to N.c. that kill 100% of the larvae during a 3 day period. Substantial mortality was obtained in most cases 48 to 72 hours after nematode exposure. Specimens parasitized by H.b. developed the typical red colour and gummy consistency of the tissues. The nematodes vary somewhat in infectivity; N.b. was demonstrably less infectious than N.c., and H.b. was moderately infective. Age of the larvae and dosages of the nematodes did not significantly affect mortality of the larvae. Nematodes reproduced normally within larval cadavers and progeny emerged 9 to 12 days after initial challenge. Field tests on barberry bushes infested with *Arge* resulted in up to 60% mortality.

INFLUENCE OF PHYTOCHEMICALS ON THE SUSCEPTIBILITY OF SOME MUNGBEAN AND URDBEAN GENOTYPES TOWARDS MAJOR INSECT PESTS AND YELLOW MOSAIC VIRUS. K.S. Chhabra*, B.S. Kooner, A.K. Saxena and A.K. Sharma, Department of Plant Breeding, Punjab Agricultural University, Ludhiana 141004, India.

Field testing of 42 promising genotypes of mungbean (*Vigna radiata* (L.) Wilczek) and 75 of urdbean (*Vigna mungo* L.) was done from 1983 to 1987 against the major insect pests: whitefly, *Bemisia tabaci* Genn.; jassids, *Empoasca* spp.; pod borers, *Lampides boeticus* L.; *Maruca testulalis* Gey., *Heliothis armigera* Hb. and mungbean yellow mosaic virus disease. Two mungbean genotypes, ML372 and ML326, and four of urdbean, UL239, UL262, UL263 and UL324, were identified to be least susceptible to the pest complex and virus in comparison to the recommended varieties: ML5 and ML131, of mungbean, M1-1 of urdbean and the 'Infestor'. Influence of biochemical components like phenols, free amino acids, reducing and non-reducing sugars on the susceptibility of pests and virus has been discussed in the paper.

STATUS OF BIOLOGICAL CONTROL OF GREENHOUSE VEGETABLE PESTS IN ONTARIO. J.L. Shipp*, Agriculture Canada Research Station, Harrow, Ontario, Canada N0R 1G0 and J.C. Fisher, Ontario Ministry of Agriculture and Food, Harrow, Ontario, Canada N0R 1G0

The use of biological control agents (parasites and predators) for greenhouse vegetable pests has steadily increased over the last decade in Ontario. Not only has the production volume of parasites and predators increased for whiteflies and spider mites, but predators are also being mass-produced for aphids and thrips. Leafminers were periodically a serious problem from 1972 to the early 1980's. Use of insecticides and natural predators eventually controlled this pest. However, aphids and thrips, especially the western flower thrips, are threatening to become important pests of greenhouse vegetables. Research is currently being conducted in Ontario and British Columbia to develop an effective biological control program for western flower thrips.

INFLUENCE DE L'ORGANISATION SPATIALE DES CULTURES DE PHASEOLUS VULGARIS ET DE LA PRECOCITE DES PLANTES DE HARICOT SUR LES ATTAQUES D'ACANTHOSCELIDES OBTECTUS.

M. Jarry, I.B.E.A.S, UA CNRS 340, Université de Pau, 64000 Pau, France.

Les processus de découverte d'une plante-hôte par un insecte phytophage s'effectuent en plusieurs étapes: localisation de la zone de culture ou de la population naturelle de la plante, pénétration dans cette zone et arrêt (au moins dans un premier temps) sur une plante particulière. Nous avons montré, chez la bruche du haricot *A.obtectus*, que la disposition des parcelles par rapport à des zones d'ombre influence la répartition des attaques qui sont significativement plus faibles dans les parties ombragées. Par contre, la présence d'adventices en fleurs sur lesquelles s'alimentent les adultes augmente nettement les attaques.

Nous savons, par ailleurs, que les plantes sont d'autant plus contaminées qu'elles sont précoces pour la maturation des gousses, dans lesquelles sont déposés les oeufs d'*A.obtectus*. Il reste à préciser la part d'un effet direct de l'ombrage sur le comportement d'exploration et de ponte des femelles, et d'un effet indirect par une action sur les plantes qui retarderait leur maturité dans les zones ombragées.

RESISTANCE TO *MARUCA TESTULARIS* GEYER (LEPIDOPTERA: PYRALIDAE) AND *CLAVIGRALLA TOMENTOSICOLLIS*, STAL (HEMIPTERA: COREIDAE) IN WILD COWPEA. L.E.N. Jackai*, S.R. Singh and N.Q. Ng. International Institute of Tropical Agriculture, P.M.B. 5320, Ibadan, Nigeria.

Two pubescent wild cowpea (*Vigna vexillata*) accessions, TVNu 72 and 73, were found highly resistant to the cowpea coreid, *Clavigralla tomentosicollis* Stal, and moderately resistant to the pod borer, *Maruca testulalis* using laboratory and field tests. Resistance to *C. tomentosicollis* is suspected to be due to antibiosis manifested through greatly reduced size of nymphs and heavy mortalities. Damage resulting from coreid infestation in field and laboratory tests was also much lower on the wild cowpea than on the cultivated susceptible check. In the case of the borer, there is disruption of larval feeding caused by pubescence; however, this effect is less pronounced in older larvae. Given a choice between cultivated cowpea varieties and the wild relatives, there was an overwhelming preference for the cultivated varieties. It is suspected that secondary plant metabolites may be playing a more important role than other factors in the observed resistance.

TESTS WITH PROFENOFOS ON COTTON BENEFICIAL ARTHROPODS IN THE FIELD B. Sechser* and M.A. Ruzette, Agricultural Division CIBA-GEIGY Ltd., Basel, Switzerland.

The effects of Profenofos on predator and prey arthropods was tested in Egyptian cotton at 750 and 500 g a.i. per ha in 1984 and 1986, respectively. Samples were taken from 250 m of cotton row six times over a period of 60 days.

The compound caused a slight reduction of adults of *Orius* and the mirid *Campylomma*, but was more severe on immature stages. The recovery of the nymphal population started two weeks after the last spray. Some suppression of these two predators has certainly to be attributed to the reduction of *Thrips*, whiteflies and jassids as their main prey source. Profenofos was quite soft on the staphylinid *Paederus*, two coccinellid species, all stages of spiders and adult hymenopterous parasitoids. The larvae of *Chrysopa* were left unharmed.

POLLUTION, ABUNDANCE OF NATURAL ENEMIES AND PRODUCTIVITY OF COTTON UNDER THE INSECT MANAGEMENT SYSTEM. V.T. Sundara-murthy, Central Institute for Cotton Research, Regional Station, Coimbatore 641 003, Tamil Nadu (India).

In India cotton production area constitutes 5 per cent of total cultivable area receives annually ca 60 per cent of total quantity of insecticides consumed in this country which by inducing ecological changes affects frequently the stability of production. The study made from 1980 to 1986 in the village commercial farms show that the management system has reduced the environmental pollution of insecticides by 53.44 per cent, decreased the residue of persistent organochlorine insecticides in the blood of farmers by 34.9 per cent, in the permanent farm men labourers by 60.51 per cent and in the breast milk of women by 76.54 per cent as against in the conventional system followed village. The abundance of native entomophages has increased by several fold with ca 50 per cent reduction in the cost of insecticides used in the management area. The mean yield of seed cotton obtained in the management area and conventional system followed area was 13.95 and 13.99 q/ha respectively with 3.38 and 6.02 per cent stained cotton.

INTRA-TREE VARIATION IN THE DISTRIBUTION OF TEA PESTS, ITS SIGNIFICANCE IN PEST MANAGEMENT.

B Banerjee, Tea Research Association, Nagrakata 735 225, West Bengal, India.

Tea phytophage species remain differentially distributed to different parts of tea canopy to avoid competition, yet exploiting the resource. Aphids, thrips and other sap-feeders mostly concentrate on succulent leaves in the centre of the plant, and leaf-eaters on the peripheral foliage. Mites damage from undersurfaces of leaves. Soft branches are preferred sites for coccids, and older branches for Bostrychids, Cerambycids and Scolytids. Roots are infested by termites.

A tea bush may have more than one multi-species phytophage guild. A guild of sap-feeders may have both insects and mites - each with different life-history strategies. Application of a particular pesticide against a specific phytophage species often upsets the functional natural enemies of other groups, thus compounding the problems of pest management. But by judicious programming of pesticide applications with pruning and picking of shoots, it is possible to optimize pest management in tea.

THE ARTHROPODA FAUNA IN APPLE ORCHARDS OF URMIEH REGION, W. AZARBEIJAN, IRAN AND THE POSSIBILITY FOR THE INTEGRATED CONTROL OF KEY PESTS. Mohammad Mostaan, P.O. Box 365, Urmieh, Iran.

To have a global idea of the Fauna of the Arthropoda and the fluctuation of their populations and to determine of their economic importance in apple orchards in Urmieh region ca. 400,000 hectares the main apple growing area of Iran, we have applied different methods including beating of branches, rearing, light traps and pheromone traps. In addition to reduce the number of chemical applications we have done a continuous research on the bio-ecology of key pests, including codling moth, european red mite and leaf miners and their control in integrated methods.

EFFECT OF ORCHARD MANAGEMENT ON THE DEVELOPMENT OF THE PHYTOPHAGOUS ARTHROPOD COMMUNITY ON APPLE. M.W. Brown, USDA-ARS, Appalachian Fruit Research Station, Kearneysville, WV, U.S.A., 25430.

Three orchards planted in 1984 have been surveyed 4-6 times a year from 1984 to the present in eastern West Virginia, U.S.A. One orchard was unmanaged, one had orchard floor management, and one was managed commercially. The survey consisted of whole-tree sampling to determine the presence of all phytophagous insect and mite species on 5-10 trees in each orchard. The objective of this survey was to compare the structure of this community in orchards of three different management regimes. Data analysis was with diversity indices and percent similarity using relative abundance data. In the first year after planting, there was little difference among orchards. In the second and subsequent years, the community in the commercial orchard was less diverse than in the other orchards. In the third and fourth years, there were subtle differences in the communities in the floor managed and unmanaged orchards. The community in the floor managed orchard had more mite and aphid species present, partially in response to the increased vigor of the trees as compared to the unmanaged trees.

STRATEGIES AND TACTICS FOR DEVELOPING FEASIBLE BIOLOGICAL CONTROL IN JAPANESE CITRUS ORCHARDS, AFTER COLONIZATION OF THE PARASITIDS OF THE KEY PEST, *UNASPIS YANONENSIS*; *AHYTIS YANONENSIS* AND *COCCOBIUS FULVUS*. Manabu Tanaka, Japanese Biological Control Implement Association, 540 Kusano, Kusano, Kurume-city, Japan.

Excellent parasitoids had been colonized successfully in 1980, from China, which is said to be the pest mother country. Since then, they have been studied biologically and ecologically, mass-produced, released, established, and are now keeping the scale population at a very low level in almost all citrus areas in Japan. Regrettably, these parasitoids have not been applied practically in commercial orchards. The barriers are problems with fruit cosmetics, present spray calendars, and marketing systems. However, improvements have been in practice in the 100 ha orchards in Hirao-town, Yamaguchi Prefecture. Use of the parasitoids not only controls the scale, but also conserves the native natural enemies of the citrus red mite etc., by saving scale-cides. As compared to the customary six or seven time spray calendars, ordinarily one or two times with petroleum oil, and occasionally one time with Maneb and Captafol used to control citrus rust mite and scab in this area. The fruits are produced with organic fertilizers with additional chemicals for taste improvement and are sold to consumer cooperatives, which permit some degree of damaged fruit and promote non-polluted delicious fruit. This biological control program exhibits the highest economic efficiency. Growers accept and practice it as a feasible biological control regime. To further develop biological control, new productive and marketing systems must be devised, with pest control strategies and tactics.

BIOLOGICAL & INTEGRATED CONTROL OF FRUIT TREES VEGETABLES

AND ORNAMENTALS IN SOME COMMERCIAL FIELDS IN ISRAEL

Amos Rubin Consultant Service for Biological & Integrated Control, 1, Keren Hayesod St. Givat Shmuel 51905, Israel

Since '83 a commercial Biological & Integrated control project was carried out in the following agricultural area:

Fruit Trees: Citrus nurseries, Carambola, Papaya & persimmon. Houseplants: Cordyline, Pandanus, Calathea, Hoya, Fittonia, Kalanchoe, Nephrolepis, Passiflora, Codiaeum. Vegetables: Cucumber, Tomato, Strawberry. The main pests especially in glasshouses were red mites and mealybugs. *Phytoseiulus persimilis* was used in control of red mites.

Leptomastix abnormis, *Leptomastix dactylopii* (Encyrtidae) were released in control of *Planococcus citri*. The above mentioned beneficials are effective where pest population is fairly low. In case of heavy infestation by phytophagous pests control was achieved by using pesticides or acaricides to which the pests were susceptible, or selective material. As a result of monitoring in intervals of every 14 days, after checking the population dynamics of pests/beneficials sprays were given when needed. No prophylactic treatments were used. The goal of producing pest free plants was achieved at lower or equal cost of former system.

INSECT PESTS AND THEIR CONTROL ON CROPS IN A CORPORATE FARMING SYSTEM IN SOUTHERN PHILIPPINES. E. R. LAYGO - DAVAO AGRICULTURAL AVIATION, INC., TADECO, DAVAO DEL NORTE PHILIPPINES.

The major crop, Cavendish bananas, is attacked by thrips, *Thrips hawaiiensis*, mealybugs *Dysmicoccus neobrevipes*, nuisance flies *Hermetia illucens* and corm weevils, *Cosmolites sordidus*. Chemicals are used for the control of all these pests. Leaf-feeders including *Parasa lepida*, *Artoria cathoxanta*, *Clania pucens* and *Erionota thrax* are minor pests. Manual collection is sometimes implemented in areas where they become important.

On pineapple, the mealybugs *D. neobrevipes* is the important pest and also the vector of the mealybug wilt virus disease. White grubs *Leucopholis irrorata* occurs in patches. Chemicals are used for their control.

The important pests of cacao are pod borers *Acrocercops cramerella* and caterpillars *Orgia postica*. Chemical control measures are used for their control. *Trichogramma* egg parasites are being tried for the control of the borers.

Rind borers *Prays citri*, mealybugs *Pseudococcus citri* and mites *Tetranychus telarius* are important on citrus. Chemicals are used for the control of these insects.

Control measures against these insects are discussed.

BIOLOGICAL CONTROL STUDY ON TYLENCHULUS SEMI-PENETRANS (COBB) NEMATODE BY CERTAIN SOIL MESO-FAUNA. G.Y. OSMAN, A.M. ZAKI*, F.M. SALEM and E.T.E. DARWISH, Plant Prot. Dept., Faculty of Agric., Menoufia Univ., Shebin El-Kom, Egypt.

A pot experiment was carried out to explore the role of macrochelid mite, Macrocheles muscae-domestica (Scopoli); and insects, staphylinid beetles, Philonthus longicornis Steph. and collembola, Onychiurus sp. singly and in combination on Tylenchulus semipetrans (Cobb) on sour orange at $29 \pm 5^{\circ}\text{C}$ & 74 ± 5 R.H. in green house. All tested soil mesofauna significantly reduced the population of nematode. The highest predation rate was achieved by the predator macrochelid mite, M. muscaedomesticae (Scapoli) singly, followed by the combination of soil mite plus collembola. The numbers of soil mesofauna recovered from soil at the end of the experiment were significantly higher in treatments of nematode plus one of each of soil mesofauna than monoinoculation of each.

IPM OF INDIAN GYPSY MOTH *LYMANTRIA OBFUSCATA* WALK (LEPIDOPTERA: LYMANTRIIDE). N.D. Rishi, Centre of Research for Development, University of Kashmir, Srinagar 190006, India.

Integration of pest management in conjuncture with the vulnerable clues in the biology, phenology and behaviour of *Lymantria obfusca*, a pest of deciduous fruit and forest trees in the Indian sub-continent, prevented 70 percent defoliation. Of the 47 natural enemies recorded, *Apanteles indianis* and *Calosoma himalayensis* have high biotic and reproductive potential for augmentation. *Euproctis signata*, *Cynathia (Vanessa) cardui*, *Polygona* sp. and *Pieris protidica* were screened as effective alternate hosts for propagation. Foliar spray of NPV at 3.5×10^6 PIB/ml at early instars resulted effective pest/parasite interaction at late larval/pupal stages. Monitoring pheromone behaviour with disparlure in IC pheromone traps and incorporating the flight date and timed with egg, eclosion, larval dispersal and development measured on DD^o basis proved effective device as "warning signals" to time action threshold with selective chemicals viz Azinphos methyl, Diflubenzuron and Fenvalerate in the pest management, with the high impact on other fruit pests.

STUDIES ON THE TEA CATERPILLAR, *EUPROCTIS PSEUDOCONSPERSA* STRAND (LEPIDOPTERA LYMANTRIIDAE) IN CHINA. Yao Wei*, Zuo Yu-ping, Shaanxi Institute of Zoology, Xian, Shaanxi, China.

The tea caterpillar is one of the main destructive tea-bush pests in China. This paper is based on the studies carried out from 1982 to 1986 in the tea garden in Shaanxi, China.

The present paper deals with its bionomics and distribution law on the tea-bush. Two important factors of controlling the pest are two major natural enemies, parasitic wasp of egg and insect virus (NPV), and the tea garden ecotone which has the great potential for the pest control.

Three effective pest control measures and control principles are discussed in the paper, which are, 1. ecological control method, 2. method of using insect virus, 3. the side-dressing and fast pesticide-spray method.

THREE-TROPHIC-LEVEL EFFECTS: FERTILIZER, BRASSICA, DIAMONDBACK MOTHS, AND A PARASITOID. D. K. Letourneau* and L. R. Fox, Board of Environmental Studies and Board of Studies in Biology, University of California, Santa Cruz, California, USA, 95064.

We manipulated foliage nitrogen levels with different fertilizer regimes in field experiments on collards, *Brassica oleracea* var. *acephala*. Given a sufficient range of N levels, density of *Plutella xylostella* was significantly correlated with nitrogen concentration in collard leaves. A constant proportion of larvae was parasitized in small-scale experiments with potted plants, regardless of density. Neither were there apparent effects of N level on parasitism rates in large field plots. However, indirect effects of nitrogen level on parasitoid sex ratio were detected: a higher proportion of female wasps emerged from moth larvae that fed on higher N plants (56% vs. 35%). These results are discussed in terms of both theory of insect-plant interaction and practical applications for biological control.

THE EFFECTS OF DIFFERENT TEMPERATURE AND TEMPERATURE HUMIDITY COMBINATIONS ON RICE MOTH, *CORCYRA CEPHALONICA* RAISING.

ZHANG JING*, YANG CHANGCHENG AND WANG JINLING, SHENYANG AGRICULTURAL UNIVERSITY, SHENYANG, LIAOLING PROVINCE, PEOPLE'S REPUBLIC OF CHINA.

The results of experiments showed that at 26°C the survival rate of larvae, the average weight and length of pupae, the rate of mature moths, the egg production and reproduction factor were all at their best. The growth, development, reproduction were adversely affected at 25°C and 28°C. The requirements for growth and development were not met at 21°C. At 26°C increasing humidity artificially in such a way as to maintain the humidity at 84% promoted notably the growth, development and reproduction of rice moth. At that point the survival rate of larvae attained 95.8%; the average weight of pupae, 31.54mg; the average length of pupae, 9.46mm.; the rate of mature moths, 55%; the egg production, 370; the population reproduction factor, 59 fold. As humidity decreased, not only was the development process retarded, but also the egg production and the reproduction factor were reduced.

HOST-ODOR MEDIATED RESPONSE OF FEMALE NAVEL ORANGEWORM MOTHS TO BLACK AND WHITE TRAPS. R.R. Youngman* and T.C. Baker, University of California, Department of Entomology, Division of Toxicology and Physiology, Riverside, California 92521.

In a mark-release-recapture experiment involving red-dyed navel orangeworm females, a black version of a Pherocon 1C pheromone trap, baited with almond oil host odor, captured over 98% of the released female moths compared to the white commercial version in side-by-side tests. Black traps also captured 6 times as many wild navel orangeworm females as compared to the white traps. Detailed observations of females flying upwind to these traps in a wind-tunnel revealed that just as many females approach the white traps as the black traps. However, a significantly higher percentage turn away from the white traps and never enter them, compared to those females which approach the black traps.

THE POTATO TUBER MOTH, A SERIOUS PEST OF PROCESSING TOMATOES IN ISRAEL. H. Podoler, and S. Gilboa, Department of Entomology, The Hebrew University of Jerusalem, Faculty of Agriculture, P.O. Box 12, Rehovot, Israel.

The potato tuber moth (*Phthorimaea operculella*) is one of the major pests of processing tomatoes in Israel. The larva attacks first the leaves and then penetrates the fruits through the stem end.

Research has been conducted, during the last two years, in order to develop a monitoring system and better control methods for this pest.

Larvae are distributed aggregatively throughout the field, with a large part of the population found at the margins. Most larvae are found on lower leaves and fruit which in contact with the soil.

Pheromone trapping of males provides only qualitative indication of changes occurring in the population.

A predictive model has been developed from data collected from pheromone traps and from samples taken at field margins. The model will be tested in the field during the 1988 growing season.

A SIMULATION MODEL OF PINK BOLLWORM (LEPIDOPTERA:GELECHIIDAE) POPULATION DYNAMICS IN COTTON: MANAGEMENT SCENARIOS. William D. Hutchison, Western Cotton Research Laboratory, USDA - ARS, 4135 E. Broadway, Phoenix, AZ, 85040, USA

A process-oriented simulation model of pink bollworm, *Pectinophora gossypiella* (Saunders), population dynamics in commercial cotton has been developed using a time-varying distributed delay to model developmental time variability of individuals in each age-class. Written in FORTRAN, the model is driven primarily by temperature and plant phenology. The model has been validated for several fields that received a multiple number of insecticide applications and for two untreated fields. Based on simulation studies with the model, the impact of various insecticide treatment criteria (i.e., timing of applications) on final yield and profit responses will be discussed.

CRITICAL CORRELATION BETWEEN THE TIME OF GOSSYPHORE APPLICATION AND THE INFESTATION OF COTTON WITH THE PINK BOLL-WORM *Pectinophora gossypiella* (Saund.). M.A.El-Adl* and A.A.Ghanim, Plant Protection Department, Faculty of Agric., Mansoura University, EGYPT.

Three pheromone formulations were applied for the control of the pink bollworm, *Pectinophora gossypiella* in about 50,000 feddans of cotton in five Governorates during 1986 season. The applications were carried out under the supervision of the Ministry of Agriculture. Results of earlier studies have shown that it is inevitable that the first pheromone treatment should start at the time of the appearance of the first pin-squares on the cotton plant. There was a diverse in the applications dates than correct time. The effect of this diverse on the development of PBW infestation have been noted and the results were discussed.

RESPONSE OF DIFFERENT DATE VARIETIES TO INFESTATION WITH CERTAIN LEPIDOPTEROUS PESTS WITH REFERENCE TO CLEANING PROCESS AS A MEASURE FOR REDUCING PEST INFESTATION. M.A.ALI*, A.L.ABDEL-SALAM, M.M.METWALLY and A.E.HUSSEIN, Department of Plant Protection, Faculty of Agriculture, Al-Azhar University, Nasr City, Cairo, Egypt.

Relative susceptibility of three date varieties (Kakea, Saidi, Soltani), commonly cultivated in Bahria Oases (Egypt), to infestation with *Arenipes sabella*, *Batrachedra amydraula*, *Cadra calidella*, *Ectomyelois ceratoniae* and *Virachola livia* was studied. It was found that with all the considered pests, saidi variety was always higher susceptible than the other two varieties. Soltani expressed the least susceptible. Infestation percentages of saidi averaged 69.5, 10.5, 0.7, 0.25, and 3.0 for *A. sabella*, *B. amydraula*, *C. calidella*, *E. ceratoniae* and *V. livia*, respectively. These rates were 33.0%, 1.8%, 29.0%, 0.25%, 0.5% and 1.5% in case of soltani variety. Cleaning process of palm trees and destruction of fallen dates markedly reduced the total infestation rate. Reduction percentages averaged 77.1, 57.3 and 53.2 for *E. ceratoniae*, *A. sabella* and *C. calidella*, respectively.

STUDY OF THE SEASONAL OCCURRENCE AND FIELD BIOLOGY OF SPILARCTIA CASIGNATA KOLLAR WITH A NOTE ON ITS NATURAL ENEMIES. M. K. Giri, Department of Zoology, Tribhuvan University, Kathmandu, Nepal.

Spilarctia casignata (Lepidoptera:Arctiidae) is a serious pest of the soybeans and other crops in Nepal. Therefore, a study on its seasonal occurrences and field biology were studied. The populations were studied at 3 locations, using 2 methods: direct observation and a sweeping net. In Kathmandu the larvae occurred from the middle of July to the beginning of October. More larvae (1.3/sample/week) were found at the end of August. The moth took about six weeks to develop from egg to adult in the field.

Feeding effect on yield by 0, 2, 4 and 6 larvae/plant at R1 stage of the plant was tested. The feeding effect by 4 and 6 larvae/plant had significant effect ($P < 0.05$) but the plants tend to recover most of the injury suffered at this stage from larval feeding.

Among the natural enemies, *Apanteles glomuratus* and *Meteorus* sp. were very common and *A. glomuratus* had 16.4 % parasitism (N=1840) in the field. *Meteorus* sp. parasitized more latter in August and September, however, lesser than *A. glomuratus*.

CERTAIN FACTORS DETERMINING MATING, FECUNDITY AND EGG FERTILITY IN THE SORGHUM STEM-BORER, *CHILO PARTELLUS*. G.C. Unnithan, International Centre of Insect Physiology and Ecology (ICIPE), P.O. Box 30772, Nairobi, Kenya.

In order to develop pheromonal pest management strategies for the pyralid, *C. partellus*, it was felt necessary to generate information on the effects of the moth's age on mating, frequency of mating, and the effects of delayed and successive matings on fecundity and egg fertility. Studies showed that the moths started mating within a few hours after eclosion, and reached a peak (80% mating) 1-2-days later. Mating in males was not negatively affected by their age up to five days, but that in the females declined steadily starting two days after eclosion ($r = -0.653^{**}$). The females usually mated only once in their life time; whereas, the males mated on an average 4.6 times within a period of 5.4 days. The first six successive matings by the male were equally effective in producing fertile eggs. Delay in mating in the females for up to 4 days did not affect their fecundity, but it reduced the egg fertility from 94 to 50%. Because of multiple mating in the males, mass-trapping of males, using pheromone traps, as a behavioural control strategy would be effective only if large proportion of males can be trapped out; on the other hand, disruption of mating appears to hold more promise in suppressing the population.

DROPLET/DOSE RELATIONSHIPS OF BIFENTHRIN ON CABBAGE LOOPER FEEDING BEHAVIOR AND MORTALITY. F. R. Hall and A. J. Adams, Department of Entomology, OSU-OARDC, Wooster, OH 44691, USA.

Monosized droplets were placed on cabbage leaf discs (2.5 cm x 2.5 cm) via a droplet generator in 2 droplet sizes (60 and 120 μ m) and an array of densities (.5 - 500/sq cm). Concentrations ranged from 7.5 gm AI/l to .0075 gm/l and late 1st instar cabbage looper (*Trichoplusia ni*) were observed over 24 hr. Mortality, feeding aversion, and leaf damage (upper and lower surfaces) were recorded in response to the quality of spray deposit. The quantity of AI deposited per leaf disc was corrected for droplet bounce (off the target areas). Halving the droplet size more than halves the quantity of AI required for a specific response. One desired effect (no feeding) may be achieved at doses that are not in themselves, lethal. Feeding impairment, or excitatory behavior may contribute to depletion of pest resources and population potentials may be limited. The study illustrates the importance of toxicant distribution and may prove to be a useful technique for assessment of pest resistance.

COLD ACID TREATMENT OF BIVOLTINE HYBRID SILKWORM EGGS, BOMBYX MORI, FOR TROPICAL COUNTRY (LEPIDOPTERA : BOMBYCIDAE) A.Manjula* & H.K.Hurkadli, Karnataka State Sericulture Development Thalaghattapura, Bangalore-62 **India**.

The popular bivoltine hybrid silkworm eggs (NB7 X NB18, KA X NB4D2, NB18 X NB7, NB4D2 X KA) have been used for the cold acid/room temperature acid treatment to prevent them from entering into diapause. Considering the different agroclimatic conditions in Karnataka/Tropical conditions, a very simple method has been evolved which assures a hatching percentage of more than 85 to 90%. These hybrids require different duration of treatment at different temperatures. The results are discussed based on the behaviour, hatching percentage of each race to different durations and temperature.

STUDIES ON ACID TREATMENT OF BIVOLTINE SILK WORM EGGS, BOMBYX MORI AT DIFFERENT HOURS OF OVI- POSITION (LEPIDOPTERA : BOMBYCIDAE) H.K.Hurkadli * & A.Manjula, Karnataka State Sericulture Development Institute, Thalaghattapura, Bangalore-62.

Sericulture is being practiced all over the Karnataka State, where depending upon the agroecological conditions the temperature and humidity vary from place to place and season. At present there is a standard procedure of hot acid treatment (artificial hatching) is available to prevent the bivoltine silkworm eggs entering into diapause. Considering the lacunae the need for identifying the safer period and range for acid treatment after different hours of oviposition during different seasons was realised and therefore the present study is taken up.

The experiment conducted at different seasons revealed that the hours and safer period of acid treatment varies from race to race at different climatic conditions.

HESSIAN FLY (DIPTERA: CECIDOMYIIDAE) BIOLOGY IN GEORGIA: GEOGRAPHIC VARIATION AND TEMPERATURE-DEPENDENT PHENOLOGY. G.D. Buntin, Department of Entomology, University of Georgia, Georgia Station, Griffin, Georgia, USA, 30223.

The population dynamics of the Hessian fly, *Mayetiola destructor* (Say), were monitored in the Piedmont (northern), upper Coastal Plain (central), and lower Coastal Plain (southern) regions of Georgia. The number of small and large larvae and puparia were determined every 7 to 14 days in two fields of volunteer or sown winter wheat at each location. Four generations were observed in the Piedmont region, but an extra spring generation occurred in the upper Coastal Plain region during the 1985/1986 season. Populations during the 1986/1987 season showed two fall and one spring generation in the Piedmont region. These generations plus a winter generation were observed in both Coastal Plain locations. Hessian fly phenology during the 1987/1988 season was similar to the phenology observed during the previous season. The first generation began about September 1 at all locations, with the phenology of the first two generations being similar at all locations. Centigrade degree-day accumulations between generations ranged from 477 to 1322 CDD using a base temperature of 1.6 C. Hessian fly population dynamics could be explained only in part using thermal-unit accumulations.

INSECTICIDE RESISTANCE IN LYCORIELLA MALI (FITCH) (DIPTERA: SCIARIDAE) AND ITS MANAGEMENT IN MUSHROOM CULTIVATION. C. B. Keil, Department of Entomology and Applied Ecology, University of Delaware, Newark, Delaware, U.S.A., 19717.

Field studies and laboratory experiments have established a pattern of insecticide resistance and cross-resistance in a pest of *Agaricus* mushrooms, *Lycoriella mali*. Field applications of permethrin, dichlorvos, and combinations indicated that resistance to these adulticides is widespread. Piperonyl butoxide did not improve toxicity of these compounds. Cross-resistance to cypermethrin was indicated although the compound was not available for use. Dose-mortality studies confirmed the development of resistance compared to a susceptible *L. mali* strain. In the laboratory, synergism by piperonyl butoxide was significant, indicating that oxidative metabolism may be the mechanism of resistance. The populations examined were also resistant to DDT, suggesting multiple resistance mechanisms. In contrast, no resistance to methoprene is apparent in *L. mali* populations although sites for oxidative metabolism are present. Permethrin resistance has a temporal dynamic associated with seasonal patterns of pesticide use. These observations and data have been used to formulate an operational model of resistance development and fluctuation. A management strategy utilizing temporal refugia for susceptibility has been developed.

STUDIES ON THE BIOLOGY AND DYNAMICS OF THE MIDGE *PRODIPLOSIS LONGIFILA* (DIPTERA: CECIDOMYIIDAE) IN LIMES. J.E. Peña and R. Duncan. University of Florida, T.R.E.C., 18905 SW 280 St., Homestead, Florida 33031.

The midge *Prodiplosis longifila* Gagne was found in limes *Citrus aurantifolia* (Christm.) Swingle flowers in southern Florida in 1984. The midge larvae were found in greater numbers in flowers infected with *Colletotrichum gloeosporoides* and its presence was correlated with flower rot. The midge has been reported feeding in *Gossypium hirsutum*, and is also known to attack beans *Phaseolus vulgaris* L., tomatoes *Lycopersicon esculentum* L., and potatoes *Solanum tuberosum* L. in South America. We describe the life history, adult emergence patterns, monitoring techniques and distribution of the midge in lime groves.

ASSESSING DENSITIES OF ADULT CARROT FLY (*PSILA ROSAE*) IN CARROT CROPS. H. Philipsen, Department of Zoology, Royal Veterinary and Agricultural University, Bülowsvej 13, DK 1870 Frederiksberg C, Denmark.

Monitoring Carrot Fly using yellow sticky traps has given valuable biological information. However, one of the drawbacks of this method is that it is very laborious.

In two years' field experiments and during the growing season 1987 a modified sticky trap has been used. The yellow sticky traps are clamped onto stalks provided with a hood of plastic netting (mesh 1.2 x 1.2 cm). The hood is 50 cm high with an oval cross section (55 cm x 30 cm). The hood serves two purposes. It attracts carrot fly, just as they were observed to be attracted to for instance tall weeds. The net also minimizes catch of a number of insect species. Some species are too big, others are less attracted to the yellow colour when it appears behind the green plastic net.

One person can serve traps from up to 100 localities with 5 traps per locality, and hence it has been possible to establish a warning system for carrot growers giving them information on carrot fly population levels. The growers can leave out insecticide treatments when there are no flies and can be helped to the best timing of necessary treatments.

EFFECTIVENESS OF CYSTIPHORA SONCHI (BREMI) (DIPTERA: CECIDOMYIIDAE) AS A BIOLOGICAL CONTROL AGENT FOR PERENNIAL SOW-THISTLE, *SONCHUS ARVENSIS* L., IN CANADA. A.S. McClay, Alberta Environmental Centre, Vegreville, Alberta, Canada T0B 4L0.

The midge *C. sonchi*, which forms galls in the leaves of perennial sow-thistle, has been established as a biological control agent for this weed at several sites in Canada. Growth analysis methods were used to assess the effect of galling by *C. sonchi*. There was no significant difference between galled and control plants in net dry matter production or net assimilation rate, nor was there any relationship between these parameters and number of galls on the galled plants. Galled plants produced significantly more shoots from root buds than did ungalled plants. The mean density of galls on the experimental plants was higher than the densities observed at any of the release sites. These results suggest that *C. sonchi* would have to increase to much greater densities than have yet been observed in the field before it would cause significant stress on perennial sow-thistle. *C. sonchi* was heavily parasitized by *Tetrastichus* sp. (Hymenoptera: Eulophidae) at Vegreville in 1987, suggesting that its population is unlikely to reach a level at which it would be an effective biological control agent.

ECOLOGICAL STUDIES OF *DIOPSIS LONGICORNIS* MACQUART (DIPTERA: DIOPSIDAE), A MAJOR PEST OF RICE IN THE REPUBLIC OF GUINEA, W. AFRICA. Hélène Chiasson, Department of Entomology, Macdonald College of McGill University, Ste-Anne-de-Bellevue, QC., Canada H9X 1C0.

Insect pests in a traditional rice cropping system (low intensive production, high species diversity, absence of pesticides) in Guinea were monitored, and effects of cultural practices studied. Key factors, such as parasitism and secondary plant hosts, were determined for the main pest, *D. longicornis*.

Guinea's recent policy to become self-sufficient in rice is leading to intensification of production. Implications of this for rice pests and their control will be discussed. Ways for traditional farmers to increase production without sacrificing sustainability or risking pest build-ups will also be examined.

FIRST FIELD APPLICATION OF OVIPOSITION DETERRING PHEROMONE OF MAIZE SHOOT FLY Atherigona COMPLEX. K.P. Salin*, K.R. Kanaujia, Department of Entomology, G.B. Pant University of Agriculture & Technology, Pantnagar, 263 145, India.

Complete protection of maize seedlings from shoot fly attack was accomplished by the field application of an oviposition deterring pheromone produced by Atherigona complex. Higher concentrations of the water soluble deterring pheromone exhibited 100% protection of the seedlings while the lowest concentration of 1 Egg Equivalent/ml showed 50% protection. The efficacy of pheromone in deterring flies from laying eggs persisted for at least 11 days without appreciable deterioration. Incorporation of this pheromone in a multifaceted control programme of shoot flies and other perspectives are discussed.

IMPACT OF SCREWORM ERADICATION IN THE REPUBLIC OF MEXICO. C. E. Hoelscher* and E. E. Davis, Texas Agricultural Extension Service, Texas A&M University System, College Station, TX 77843.

A study was conducted in 1985 and 1986 to determine the impact of screwworm eradication in the Republic of Mexico. B/C ratios were developed for the major classes of livestock in terms of benefits to Mexican producers. The country was divided into 9 survey areas depending on the date eradication was achieved. Data was field collected using 2,800 surveys. Costs were determined for veterinarian services, medical supplies, insecticides, animal confinement and equipment for treatment. Discount rates of 3%, 6% and 8.625% were used to project program returns. Results indicated a return of 4.5:1 for each U. S. dollar invested in screwworm eradication to the Mexican livestock owner. Study results are available in three sections which deal with economic impact, technology transfer and the screwworm outbreak study conducted in the summer of 1985 in the Mexican states of Tamaulipas and San Luis Potosi. Screwworm eradication was achieved north and west of the Isthmus of Tehuantepec by late 1984. The Yucatan area in southern Mexico has been eradicated except for 5 to 10 active cases per week occurring adjacent to the Belize and Guatemalan borders. Eradication programs are planned for all Central American Countries including Panama.

LABORATORY AND FIELD STUDIES OF RESISTANCE OF CRAB APPLE SELECTIONS TO THE APPLE MAGGOT, Rhagoletis pomonella (WALSH). W. H. Reissig*, S. K. Brown, R. C. Lamb, and J. N. Cumins, Department of Entomology, NYS Agric. Expt. Station, Cornell University, Geneva, New York 14456.

Apple maggot (AM) Rhagoletis pomonella (Walsh) oviposition and larval survival varied significantly among fruit from 25 crabapple selections evaluated in field and laboratory studies. In general, flies oviposited more in selections with larger fruit, although the relationship between fruit diameter and the average number of oviposition punctures was more significant in laboratory tests when fruit was infested by laboratory reared flies than when fruit were naturally infested in the field with wild flies. Fruit of 'Aldenhamensis', 'Fugi', 'Zumibalocarpa', 'Vimorin', and 'Hupehensis' was not infested by AM in the field, but flies oviposited in fruit of all 25 selections in choice tests in the laboratory. AM larvae did not survive in fruit of 'H. F. DuPont', 'Frettingham', 'Fugi', 'Hupinenses', 'Sparkler', and 'Zumi', and larval mortality was very high in fruit from 'Vilmorin', 'Sparkler', 'NA40298', 'Hennetta Crosby', 'Golden Gem', 'Malus baccata', and 'Almey'. AM eggs hatched in fruit of these resistant selections, but larvae died during their early instars.

EFFECTS OF TWO INSECT GROWTH REGULATORS ON LARVAE AND PUPAE OF THE CABBAGE MAGGOT, Delia radicum (L.). R. Gordon*, T. L. Young, M. Cornect and D. K. Hong, Department of Biology, Memorial University of Newfoundland, St. John's, Newfoundland, Canada, A1B 3X9.

Eclosion to the adult stage was reduced in a dose-related fashion, consequent to topically treating post-feeding larvae or recently-molted pupae of D. radicum with the juvenoid methoprene. The fecundity of adults that developed from methoprene-treated larvae and pupae was not reduced.

Eclosion and adult fecundity of insects, treated as larvae with the chitin synthesis inhibitor diflubenzuron, was the same as in controls. However, eclosion was significantly suppressed by treatment of pupae with diflubenzuron and adults that did develop oviposited fewer eggs (cf. controls), with impaired capacity to hatch.

Insect growth regulators may constitute a potentially useful control strategy for agricultural pests such as D. radicum.

BIOLOGICAL RESPONSES OF WESTERN CORN ROOTWORM, *DIABROTICA VIRGIFERA VIRGIFERA* LECONTE (COLEOPTERA: CHRYSOMELIDAE) ADULTS TO SEMIOCHEMICALS. H. Oloumi-Sadeghi*, E. Levine, R.L. Metcalf, and R. Lampman, Office of Agricultural Entomology, University of Illinois, Champaign, Illinois 61820.

Yellow sticky traps baited with TIC mixture (1:1:1 of 1,2,4-trimethoxybenzene, indole, and trans-cinnamaldehyde) or PMeO (para-methoxycinnamaldehyde) and blank traps were placed around the perimeter of an isolated corn field. Two beetle releases were made in August, 1987. Prior to release, sex ratio and reproductive status of the adults were determined. Traps were visited daily and marked and unmarked beetles and their sex ratios and reproductive status were measured. Abundance, sex ratio, and ovarian development of the main field populations were also determined. Results indicated that: PMeO and TIC traps were similarly effective and caught ca. 20 fold more beetles than the check traps; number of beetles per plant declined sharply during the first week of trapping; approximately 20% of the marked beetles were recovered, 90% of which took place during the first week of trapping; baited traps were more attractive to the females than to the males; wind direction had no influence on the number of beetles caught in the traps; distance of the traps from the release point affected the trap catch; and corn phenology influenced the attractiveness of the traps.

POPULATION DYNAMICS OF THE VIBURNUM LEAF BEETLE AND INFLUENCES OF CONVENTIONAL PRUNING OPERATIONS. H. Amano*, N. Shinkaji and M. Nunokawa, Faculty of Horticulture, Chiba University, Matsudo, Chiba, 271 Japan.

During the course from 1983 to 1987, development and seasonal dynamics of *Pyrrhalta humeralis* (Chen) (Coleoptera: Chrysomelidae) were investigated on a hedge of an evergreen broad-leaved host tree, *Viburnum awabuki*, a popular ornamental and greening tree in Japan. Throughout immature and adult stages, the beetle suffered a light mortality from predators and parasitoids. Instead, two natural and an artificial mortalities were found and thought to be important for their dynamics.

The first factor was a loss of young larvae along the fall of buds and new leaves in early spring, due to the feeding damage. Interestingly, this factor worked in a density-dependent manner and reduced the density drastically. The second factor was a mortality caused by entomogenous fungi, *Beauveria bassiana*, attacking mainly pupae in soil. Considerable variability existed for this factor in space and year. The last factor was traditional pruning operations commonly used in Japan. This annual practice of reshaping hedges also removed many egg masses of the beetle deposited on the branches (when pruned in winter) or removed branches suitable for beetles to deposit their egg masses in the following autumn (when pruned in summer).

EFFECTS OF TIMING AND INTENSITY OF DEFOLIATION BY COLORADO POTATO BEETLE ON TUBER YIELD OF POTATO PLANTS. Derek J. Lactin, Department of Entomology, University of Manitoba, Winnipeg, Manitoba, Canada, R3T 2N2.

Colorado potato beetles reduce leaf area of potato plants, and thus indirectly affect marketable tuber yield. Therefore, economic injury level estimates formulated as a number of insects per plant or per unit area can be improved by relating this number to leaf damage.

This talk presents a model of the impact of Colorado potato beetles on tuber yield of Russet Burbank potato plants. According to this model, economic injury level estimates should consider the timing of infestation, as well as its intensity. This type of model may pertain to all crops in which pests reduce yield indirectly.

WHITE GRUBS IN SPORTFIELDS AND LAWNS: THEIR SIGNIFICANCE, AND BIOLOGICAL AND CHEMICAL CONTROL. H.J. Vlugg, Research Institute for Plant Protection, P.O. Box 9060, 6700 GW Wageningen, The Netherlands.

White grubs of *Amphimallon solstitiale*, *Phyllopertha horticola* and *Anomala dubia* destroy turf grasses on high sandy soil in the Netherlands. Secondary damage, caused by predators like crows and foxes, is even a greater problem. Parasitic nematodes as biological control agents were successfully applied against grubs in bio-assays but failed to show sufficient control in field situations. Most of the effective soil-insecticides are too toxic as surface application to sportfields and lawns. Some granular formulations give positive results but slot-seeding is hampered by dosage problems with the present-day machinery.

CHLOROPHORUS VARIUS MULL. (COLEOPTERA: CERAMBYCIDAE), AN IMPORTANT PEST IN VINEYARDS IN EGYPT. S.I. El-Sherif and A.W. Tadros, Department of Economic Entomology and Pesticides, Faculty of Agriculture, Cairo University, Giza, Egypt.

The wasp beetle, *Chlorophorus varius* Mull., is a serious pest threatening vineyards in Egypt. Larvae bore into the stems and branches of vine trees causing their weakness, breakage and finally death. In badly attacked yards, infestation reached 92%. Population studies for 3 successive years indicated that beetles emerged between April and September with high abundance throughout May-July. Infestation increased from 2.2 beetles/tree in 1978 to 9.8 beetles/tree in 1980, i.e. about 4 folds within a couple of years. Beetle emergence was significantly influenced by both day-maximum and daily-mean temperatures 4.5 to 5 months before emergence as well as daily mean R.H. 1.5 months before emergence. Insecticidal application to combat *C. varius* in vineyards in Egypt were recommended to start by early May.

OCCURRENCE AND MANAGEMENT OF PYRETHROID RESISTANCE IN PEAR PSYLLA (*PSYLLA PYRICOLA* FORSTER) POPULATIONS IN SOUTHERN ONTARIO. D.J. Pree, Agriculture Canada, Research Station, Vineland Station, Ontario, Canada L0R 2E0

Resistance to pyrethroid insecticides, first shown from one location in 1986, was extended to several others in 1987. Resistance was highest to fenvalerate and permethrin but cross resistance to all other pyrethroids tested was indicated. Addition of synergists did not result in increased toxicity. Pyrethroid resistance declined when selection pressure was removed.

LIFE TABLES AND BIOLOGICAL CONTROL OF WHITE WAX SCALE, *GASCARDIA DESTRUCTOR* (NEWSTEAD), AND CHINESE WAX SCALE, *CEROPLASTES SINENSIS* DEL GUERCIO (HEMIPTERA: COCCIDAE). G.A.C. Beattie, Department of Agriculture Biological and Chemical Research Institute, PMB 10, Rydalmere, NSW, 2116, Australia.

White wax scale (WWS) life tables indicate that a number of factors are responsible for high instar mortality and the scale's decline from major to minor importance since 1970 on New South Wales (NSW) coastal orchards. These include parasitoids introduced from the scale's native Africa, disease, changes in the use of fungicides and the presence of Chinese wax scale (CWS). The parasitoids include the endoparasitoids *Paracraproceroes nyasicus* (Compere) and *Anicetus communis* (Annecke) (>85% of endoparasitoids), and the ectoparasitoid/egg predator *Scutellista cyanea* Motschulsky. Parasitism by *S. cyanea* can exceed 60% in early third instar scales but a large proportion die before they mature. This mortality is associated with high host mortality.

CWS, first recorded in NSW in 1966, is considered native to East Asia. Heavy infestations are becoming increasingly common on coastal orchards and are reminiscent of severe WWS infestations. Life tables clearly indicate that the scale is not under effective biological control because of moderate second and early third instar mortality and highly variable parasitism (<10 to >70%) of gravid hosts by *S. cyanea*. Parasitism of second and immature third instar scales is very low and introduction of natural enemies of these stages could stabilize populations at uneconomic levels. Both scales and their asynchronous phenologies seem to be essential for *S. cyanea*'s survival.

FIELD SCREENING OF DISSULFOTON, CARBOFURAN, ALUMINUM PHOSPHATE, AND ALDICARB IN THE CONTROL OF THE BRAZILIAN GROUND PEARL *EURHIZOCOCCUS BRASILIENSIS* (HOMOPTERA: MARGARODIDAE) IN VINEYARDS IN SOUTHERN BRAZIL. S. de J. Soria, EMBRAPA/CNPV, C.P. 130, 95700 - Bento Gonçalves, RS, Brazil.

A screening of following insecticides and dosages, respectively: dissulfoton, 5 kg active ingredient per hectare (a.i./ha), carbofuran 2.5 kg a.i./ha, aluminum phosphate 8.0 g a.i./ha, aldicarb 5 kg a.i./ha was carried out in field conditions in order to determine levels of technical efficacy in the control of *Eurhizococcus brasiliensis*. This is a severe pest of the root system of vineyards in Southern Brazil. Chemicals were applied and incorporated in the soil with the help of ordinary agricultural equipment. Formulates used were granulates, except for aluminum phosphate which came as pills. Correction of mortality was made utilizing Henderson and Tilton equation. Results indicated following chemicals arranged in decreasing order of technical efficacy: dissulfoton, 60 to 16% mortality level, carbofuran 56-36%, aluminum phosphate 50-43%, and aldicarb 46-4%. There was no significant difference in their mortality rates at 5% probability level.

#42

POPULATION STUDIES OF PREDACIOUS ARTHROPODS ASSOCIATED WITH ICERYA AEGYPTIACA (DOUGLAS) (HOMOPTERA:MARGARODIDAE). M. M. Abd El Rahim, A. El Nabawi and A. A. Osman, Plant Protection, Department, Faculty of Agriculture, Menoufia Univ. Shebin El Kom.

The Egyptian mealy-bug, Icerys aegyptiaca (Douglas), is of economic importance causing a great damage to fruit trees, wood trees and ornamental plants. Population studies of predacious arthropods associated with this mealy-bug revealed that predators belonging to five families of mites and two families of insects. The mite families were: Phytoseiidae, Tydeidae, Hemisarcopidae, Stigmeidae and Tarsonemidae. While the two families of predacious insects were coccinellidae and chrysopidae.

Icerya aegyptiaca has two generation a year, one appears in April and one in November.

Data obtained showed that the different predators of different families caused an insignificant negative effect on Icerya aegyptiaca under field conditions.

#43

BIOLOGY AND CONTROL OF ANOPLOPHORA MALASIACA THOMSON (COLEOPTERA: CERAMBYCIDAE) IN CITRUS GROVES. I. Adachi * and R. Korenaga, Okitsu Branch, Fruit Tree Research Station, MAFF, Okitsu, Shimizu, Shizuoka, 424-02 Japan.

The white-spotted longicorn beetle, A. malasiaca, is the most important wood-infesting pest in citrus trees in Japan. Larvae bore into the living trunk through egg-laying scars and destroy the xylem during their long developmental periods, which causes the deterioration and/or the death of trees resulting in serious economic damage. Because of difficulties in controlling larvae, we mainly investigate the biology and the population ecology of adults to establish control measures for them. The census with the mark-recapture method showed that adults emerged from June to early July and tended to be distributed clumpedly on trees. The degree of spatial overlapping between male and female changed seasonally. Correspondingly, the distance of dispersal also changed seasonally. Adult females deposited on an average 200 eggs in their life span of about 80 days. Oviposition sites were almost located in the bottom part of the trunk, and eggs were distributed clumpedly on trees. To protect trunks from the oviposition, four kinds of control measures were examined in the citrus groves.

#44

FEEDING BEHAVIOR OF DEFOLIATING INSECTS IN A GREENHOUSE PROGRAM FOR MASS SCREENING OF SOYBEAN FOR PEST RESISTANCE. J.N. All*, R.H. Boerma and J.W. Todd, Departments of Entomology and Agronomy, University of Georgia, Athens, USA, 30602.

The feeding behavior of the corn earworm, Heliothis zea (Boddie), soybean looper, Pseudoplusia includens (Walker), velvetbean caterpillar, Anticarsia gemmatilis Huebner, green cloverworm, Plathypena scabra (Fabricius), beet armyworm, Spodoptera exigua (Huebner), fall armyworm, Spodoptera frugiperda (J. E. Smith), and the Mexican bean beetle, Epilachna varivestis Mulsant, was studied using a greenhouse procedure developed for mass screening of soybean cultivars for insect resistance. All species showed similarities in behavior, all were inhibited by cultivars such as PI229358 which is known to have cross insect resistance. However, important differences in preference, injury, and survival on test plants were exhibited by different insect species. Insect injury to soybeans in the 14 day greenhouse test was correlated to the damage occurring to the cultivars in season long field tests.

#45

EFFECT OF TEMPERATURE ON PROGENY PRODUCTION AND SEX RATIO OF APANTELES SP. GROUP ULTOR [HYMENOPTERA:BRACONIDAE]- S.K. Al-Maliqy, Department of Plant Protection, Faculty of Agriculture and Biology. P.O. Box 765. Baghdad, Iraq.

The reproduction performance of Apanteles sp. group ultor as a control agent of Ectomyelois ceratoniae was evaluated under the following temperatures 15, 20 and 29°C. Two set of adults were used first, single mated female and second, virgine female with male exposed immediately to each temperature to know its effect on mating. The mating behavior of both sex exhibited polygamous mating habits. There were an inverse relation between temperature and longevity of adults and reproductive period of females. It was successfully parasitized at the three temperature mentioned. Higher number of females produced at 29°C compared with 15 and 20°C.

#46

IPM IN TOMATO CROPS IN CATALONIA (SPAIN). O. Alomar*, C. Castañé, R. Gabarra, E. Bordas, J. Adillón and R. Albajes, I.R.T.A. Centre d'Investigació Agrària de Cabrils, 08348 Cabrils, Barcelona. Spain.

Tomato is an important crop in Spain both outdoors and in greenhouses. IPM programs are being developed in Catalonia (NE Spain) against its major pests, the greenhouse whitefly Trialeurodes vaporariorum (Hom; Aleyrodidae) and agromyzid leafminers (Liriomyza spp.).

In spring, control of these pests in the greenhouse is successful with mass releases of Encarsia formosa and Diglyphus isaea. Presently this method is being used in 5 Ha of greenhouse production. Further implementation will depend on availability of these natural enemies.

During summer, naturally occurring predatory bugs (Dicyphus tamaninii and Macrolophus caliginosus Het.: Miridae) are abundant in open field tomatoes. Nevertheless, D. tamaninii is partially phytophagous and feeds on tomato fruits when pest levels are low. By using short-persistence insecticides it is possible to maintain a balance between pests and this predator thus minimizing damage. A substantial reduction in the number of sprays is still achieved.

#47

RESIDUAL ACTION OF SLOW RELEASE SYSTEMIC INSECTICIDES ON RHO PALOSIPHUM PADI (L.) (HOMOPTERA: APHIDIDAE) ON WHEAT IN THE LABORATORY. J.E. Araya*, J.E. Foster, M.M. Schreiber and R.E. Wing, Department of Entomology, Purdue University, W. Lafayette, Indiana 47907, USA.

Slow-release formulations of acephate and carbofuran encapsulated in pearl cornstarch or corn flour granules were applied to the soil at seeding time of potted 'Caldwell' wheat in the laboratory at dosages adjusted to a standard of 10 kg/ha of a 10% granular formulation of carbofuran. The residual action of these insecticide treatments against Rhopalosiphum padi were compared with those obtained with foliar sprays of solutions of acephate (75% EC) at 0.2% and carbofuran (4% FW) at 1.25%, applied 12 days after seedling emergence. The slow-release granular formulations began to provide control (50% aphid mortality) on days 13.3-17.9 after seeding. They controlled the insect until days 34.3-35.5 after seeding. The foliar sprays of acephate and carbofuran provided control during 18.3 and 36.2 days, respectively. The selective control of R. padi obtained with the slow-release granular formulations is discussed in relation with the importance of this aphid as vector of barley yellow dwarf virus, particularly at early stages of wheat development.

#48

PREFERENTIAL FEEDING BY *ADORETUS SINICUS* BURMEISTER (COLEOPTERA: SCARABAEIDAE) ON ETHEPHON TREATED PLANTS. L.H. Arita*, S.C. Furutani and J.J. Moniz, College of Agriculture, University of Hawaii at Hilo, Hilo, Hawaii, USA 96720-4091.

Preferential feeding by the Chinese rose beetle, *Adoretus sinicus* Burmeister on ethephon [(2-chloroethyl) phosphonic acid] treated host leaves was found under field and caged conditions. In field trials, edible ginger, *Zingiber officinale* Roscoe leaves showed progressively greater feeding damage with increasing concentrations (0, 500, 1000 ppm) of ethephon. Similar feeding responses by the beetles were found on ginger and snap bean, *Phaseolus vulgaris* L. leaves treated with 1000 ppm ethephon under caged conditions. Olfactometer experiments confirmed preferential movement of the beetles toward ethephon treated ginger plants and indicated that the movement was not due to: 1) the ethephon treatment itself or 2) ethylene gas which is present in ethephon and which continues to be produced in the plant following treatment. It appears that the high levels of ethylene gas found in ethephon treated plants is involved in the formation of a plant volatile(s) which serves as an attractant and feeding stimulus for the Chinese rose beetle.

#49

EVOLUTION OF INTEGRATED CONTROL IN FRENCH APPLE ORCHARDS. H. Audemard, I.N.R.A. Domaine St. Paul 84140 Montfavet (France) F. Colliot*, Rhône-Poulenc Agrochimie B.P. 9163 - 69263 Lyon Cedex 09 (France), J.-P. Gendrier, J.-N. Reboulet, A.C.T.A. 149 Rue de Bercy 75595 Paris Cedex (France)

In French apple orchards there are about 9 species of arthropods (*Cydia pomonella* L., *Panonychus ulmi* Koch, *Dysaphis plantaginea* Pass., *Adoxophyes orana* F.v.R., *Pandemis heparyana* Den. and Schiff., *Synanthedon myopaeformis* Borkh., *Zeuzera pyrina* L., *Aphis pomi* de Geer, *Cydia molesta* Busck.) and two fungal diseases (apple scab *Venturia inaequalis* (Cke) Wint. and powdery mildew *Podosphaera leucotricha* Ell. and Ev.) that require at least two sprays per year. However usually 2 to 4 main arthropods will be sprayed.

In a given season use of computer models has improved and simplified the risks of forecasting for pests and diseases such as codling moth and apple scab.

Routine studies on short term effect of pesticides on beneficial arthropods are carried on and the results taken into account in supervised control programmes in apple orchards. More long term effects must be examined, especially for new compounds such as insect growth regulators.

Some biological and biotechnical methods of control have been successfully experimented, for example : granulosis virus and mating disruption technique against codling moth, releases of organo-phosphate resistant Phytoseiides against *Panonychus ulmi* Koch, as well as the use of cultivars resistant (tolerant) to apple scab, powdery mildew and *Dysaphis plantaginea* Pass injuries.

#50

EVOLUTION OF INTEGRATED CONTROL IN FRENCH APPLE AND PEAR ORCHARDS. H. Audemard, I.N.R.A. Domaine St. Paul 84140 Montfavet (France), F. Colliot*, Rhône-Poulenc Agrochimie B.P. 9163 - 69263 Lyon Cedex 09 (France), J.-P. Gendrier, J.-N. Reboulet, A.C.T.A. 149 Rue de Bercy 75595 Paris Cedex 12 (France)

In French apple and pear orchards there are about 10 species of arthropods and 4 fungal diseases that require at last two sprays per year. However usually 2 to 4 main arthropods, principally *Cydia pomonella* L. and *Psylla pyri* L.. will be sprayed.

In a given season use of computer models has improved and simplified the risks forecasting for pests and diseases such as codling moth and apple scab.

Routine studies of short term effects of pesticides on beneficial arthropods are carried on and the results taken into account in supervised control programmes in apple and pear orchards. More long term effects must be examined.

Some biological and biotechnical methods of control have been successfully experimented, for example : granulosis virus and mating disruption technique against codling moth, releases of *Anthracorhis nemoralis* F. against *Psylla pyri* L., releases of organo-phosphates resistant Phytoseiides against *Panonychus ulmi* Koch, as well as the use of cultivars resistant (tolerant) to apple scab, powdery mildew and *Dysaphis plantaginea* Pass injuries.

#51

THE ROLE OF NATURAL ENEMIES IN THE CONTROL OF CITRUS RED SCALE, *AONIDIELLA AURANTII* (MASKELL) (HEMIPTERA: DIASPIDIDAE) G.A.C. Beattie* and M.D. Huang, Department of Agriculture, Biological and Chemical Research Institute, P.M.B. 10, Rydalmere, NSW, 2116, Australia and Guangdong Entomological Institute, 105 Xingang West Road, Guangzhou, Guangdong, People's Republic of China.

Contention surrounds the role of natural enemies in the biological control of citrus red scale. Most citrus entomologists believe that parasitoids are more effective than predators and that the ectoparasitic *Aphytis* species are more effective parasitoids than the endoparasitic *Encarsia* and *Pteroptrix* species and *Comperiella bifasciata* (Howard).

Data from China and Australia are presented which question the validity of these beliefs. These data indicate that the most effective natural enemy of red scale on bearing trees in the scale's native East Asia may be a predatory thrips, *Aleurothrips fasciapennis* (Franklin), and that the most effective parasitoid is *C. bifasciata*. They emphasise the need for the construction and analysis of life tables. Resolution of these issues is essential for the effective use of biological and integrated control programs.

#52

BIOLOGY AND MANAGEMENT OF WHITE APPLE LEAFHOPPER IN WASHINGTON. E.H. Beers* and E.A. Elsner, Department of Entomology, Washington State University, Tree Fruit Research and Extension Center, Wenatchee, Washington, USA 98801.

Leafhopper management in Washington is aimed primarily at the first generation. Optimum pesticide timing is at petal fall, using endosulfan or formetanate hydrochloride. Resistance to organophosphates appears to be prevalent. Control of the second generation may be accomplished in mid-August to avoid annoyance of pickers by adult leafhoppers at harvest. Injury level studies to date indicate no reduction in fruit size or leaf photosynthesis due to leafhopper damage.

#53

LIFE-TABLES FOR DETERMINING KEY MORTALITY FACTORS OF *HELIOTHIS ARMIGERA* (HUBNER) AT PARBHANI IN INDIA. G.G. Bilapate, Department of Entomology, Marathwada Agricultural University, Parbhani, India.

Heliothis armigera (Hubner) is one of the important pests of cotton, pigeonpea and chickpea in Marathwada region of Maharashtra, India. Population studies of *H. armigera* were made on cotton during 1979-80 to 1981-82. *H. armigera* completed five generations on cotton. *Compolatis chlorideae* Uchida, *Carcelia* sp., *Gonipphthalmus halli* Mesnil and nematodes were key mortality parameters of *Heliothis* on cotton. The increasing trend of population was up to second generation and declined thereafter. *Heliothis* passed through three generations on pigeonpea from 1979-80 to 1983-84. *C. chlorideae* was an important key factor for mortality of *Heliothis* larvae on chickpea. The other parasites viz., *Chelonus* sp., *Eriborus argenteopilosus* Cameron, *Ericospilus biconatus* Townes, Townes & Gupta and *Palexorista* sp. were recorded during the crop season. The food preference of *Heliothis* in the field was in the ascending order of cotton, pigeonpea and chickpea.

#54

BEAN GENOTYPES RESISTANCE TO *BEMISIA TABACI* (GENN., 1889) AND *EMPOASCA KRAEMERI* ROSS & MOORE, 1957. A.L. Boiça Junior*, J.D. Vendramin and F.M. Lara, Departamento de Biologia, FEIS/UNESP, 15.378, São Paulo, Brazil.

The experiments were carried out in Ilha Solteira, SP, Brazil, from 1981 to 1984, with the objective to study the behaviour of bean genotypes in respect to *Bemisia tabaci* and *Empoasca kraemeri* attack. They were evaluated the number of eggs and nymphs of *B. tabaci*, and the plant age influence using 15-30-45 and 60 days-old-plants after emergence on the insect oviposition as well as the biological cycle from eggs to adults. For *E. kraemeri* they were evaluated the number of nymphs and adults attacking the genotypes. The following results were obtained: 1) for *B. tabaci*: at the condition of low infestation in dry season; the BAT 85 genotype showed to be more susceptible to the pest attack; the BAT 363 genotype was the most resistant; the period of high pest attack was concentrated on the first 45 days of plant age; and, the cycle of egg-adult was longer on Bolinha and BAT 363 genotypes; 2) For *E. kraemeri*: the BAT 363 genotype was the most resistant; the more susceptibles was Goiano Precoce, Bolinha and BAT 85, and, the infestation of this insect was higher in the rain season than in the dry season.

#55

LOSS OF SUSCEPTIBILITY TO MITICIDES IN FIELD POPULATIONS OF BANKS GRASS MITES, *OLIGONYCHUS PRATENSIS* (BANKS) (ACARI: TETRANYCHIDAE), FOLLOWING FIELD EXPOSURE TO PESTICIDES. L.L. Buschman* and M.A. Chowdhury, Department of Entomology, Kansas State University, 4500 East Mary Street, Garden City, Kansas 67846 USA.

A bioassay using glass vials coated with dimethoate, methidathion or biphenthrin was conducted to monitor changes in susceptibility of field populations of Banks grass mites following field exposure to commonly used pesticides. Mites taken from plots that had been sprayed only once were often less susceptible (higher LC 90's) to test miticides than mites taken from untreated plots. A single application of some chemicals reduces the susceptibility of mite populations and may explain some field control failures of miticides.

#56

CONTROL OF THE COTTON PESTS IN BRAZIL BY SEXUAL PHEROMONES.

A.C. BUSOLI - Departamento de Entomologia e Nematologia - FCAV-UNESP-14870-Jaboticabal, SP, Brazil.

This experiment shows the results of the use of two pheromones gossypure (25 g/ha) and viresure (50 g/ha) in the control of *Pectinophora gossypiella* and *Heliothis* spp., respectively, by "mating disruption method". The adults were monitored with the respective pheromones traps, as well yours infestations in the bolls. The results were compared with those obtained in other cotton farm in which it was made 7 conventional insecticides sprayings. The results showed that the application of the IPM concepts plus pheromones reduced 90% the quantity of A.I. insecticides, and 3-folds less the cost to produce the same amount of fibers, when compared with conventional sprayings. The cotton pheromone field presented a reduction of 78% in the population of the pink bollworm males while in the conventional insecticide field it was observed a reduction of more than 74% in the natural enemy density.

#57

BEHAVIORAL CONTROL OF ANTS OF THE GENUS *Atta* (HYMENOPTERA-FORMICIDAE) BY DIFLUBENZURON BAITS. - A.C. BUSOLI & O. A. FERNANDES - Departamento de Entomologia e Nematologia. FCAV-UNESP-14870-Jaboticabal, SP, Brazil.

The different concentrations of diflubenzuron were tested in baits to verify the attractiveness and control of ants of the Genus *Atta*, in the São Paulo State, Brazil. During 1986/87 the baits were produced with concentrations of 6, 12, 20 and 40ppm of diflubenzuron, which were compared with standard commercial bait (Mirex[®]) and untreated anthill. For *A. capiguara*, *A. sexdens rubropilosa*, and *A. sexdens sexdens* were used, eight, three and one replications (anthill) per treatment, respectively. The baits were placed at 0.5 m and 1.5 m of the initial way out. During the experiment, the activity of the anthills were monitored. The averages of ants/10cm/min. of the initial way out were determined. The results obtained in this experiment showed that diflubenzuron baits presented better attractiveness and efficiency than commercial baits in the control of these ants in Brazil, and also a promising product in the substitution of organo-chlorides in the control of ants.

#58

THE ASSESSMENT OF THE EFFICACY AND PROFIT FOR CONTROL OF *ZEUZERA COFFEAEE* NIETNER (LEPIDOPTERA: COSSIDAE) ON GRAPEVINE. C. P. Chang, Taichung District Agricultural Improvement Station, Changhua, Taiwan, Republic of China.

This study was conducted to find the way for increasing the efficacy for control of *Zeuzera coffeae* and assessing the profit of control measures. As the adult emergence periods fall on April to June and August to October, then those seasons are considered to be the most favorable season to take some control methods. The four times of insecticidal application for the first emerging season and three times application for the second emergence obtained highest control effect and net profit. The establishment of assessment level of control for each branch, there are 0.7 twig for the 1st branch (main stem), 1.6 twigs for the 2nd branch, 3.3 twigs for the 3th branch, 16.7 twigs for the 4th branch and 25.6 clusters of grape for cluster axis. 2.8% Deltamethrin E.C. 2000-fold dilution, 2.8% Deltamethrin E.C. 1000-fold dilution and 10% Permethrin E.C. 1000-fold dilution were more effective than any other chemicals tested for controlling this borer.

#59

ASSESSMENT OF *HELIOTHIS ARMIGERA* (HUB.) POPULATION THROUGH PHEROMONE TRAPPING. K.S. Chhabra* and B.S. Kooner, Department of Plant Breeding, Punjab Agricultural University, Ludhiana 141004, India.

Population dynamics of the gram pod borer, *Heliothis armigera* (Hub.) have been assessed through synthetic pheromone traps, installed in experimental areas. Daily trap catches taken from 1982 to 1987 have been correlated with the weather parameters. Best peaks were recorded in October, for rainy season grain legume crops and in March-April for winter season grain legume crops.

#60

COMBINATION STUDIES WITH THE DITHIOCARBAMATE FUNGICIDES: ZINEB, MANCOZEB OR CARBAMATE AND SELECTED ACARICIDES FOR THE CONTROL OF THE CITRUS RUST MITE, *PHYTLOCOPTURUS* OLEIVORA (ASHMEAD) ON CITRUS. C.C. Childers, University of Florida, IFAS, Citrus Research and Education Center, 700 Experiment Station Road, Lake Alfred, FL 33850, USA.

A series of field experiments were conducted between 1981 and 1987 to evaluate the potential of zineb, mancozeb or carbamate in combination with one or more of the following acaricides for the control of the citrus rust mite: ethion, dicofol, propargite, chlorpyrifos, fenbutatin-oxide, carbosulfan, formetanate or amitraz.

Treatments were applied to replicated large plots using an air-carrier sprayer or to replicated single tree plots using a hand-gun from a trunk-mounted sprayer during the postbloom, summer or supplemental fall spray periods. Results of these experiments are presented including post-treatment efficacy comparisons with the fungicide alone, the acaricide alone and one or more combinations of the fungicide + acaricide. Cumulative mite-day data and damage rating comparisons of citrus rust mite injury to fruit are presented.

#61

THE APHID, *RHOPALOSIPHUM PADI*, AND ITS POLYPHAGOUS PREDATORS: INTERACTIONS IN SPRING CEREALS IN SWEDEN. P.A. Chiverton, S. Wiktelius, H. Wallin, B.S. Ekbo, Department of Plant and Forest Protection, Swedish University of Agricultural Sciences, Box 7044, S-750 05 Uppsala, Sweden.

Polyphagous predators have been shown to be important in limiting the increase of bird-cherry oat aphid (*Rhopalosiphum padi*) in spring cereals. Experiments have also shown that the use of insecticides may have some negative effects on polyphagous predators. Cereal fields were surveyed using pitfall traps. The predator complex varied from field to field but the cumulative number of polyphagous predators up to aphid peak was shown to have a negative relationship with the number of aphids at peak. Manipulative field experiments using barriers to exclude predators showed the same negative relationship between predator occurrence and aphid density.

Further studies showed that spiders and spring breeding carabids can be important for *R. padi* population levels. The searching behavior and consumption rates for two spring breeding carabids were studied. The results were used in simulation models to determine the capacity of these predators to limit aphid numbers. Life histories, habitat preference and movement behavior of several field-living carabids were also studied in order to suggest methods for improving predator environments.

#62

INFLUENCE OF SOIL ENVIRONMENTS ON THE INFECTIVITY OF HETERORHABDITIS HELIOTHIDIS (RHABDITIDA: HETERORHABDITIDAE) TO INSECT HOST. H. Y. Choo, H. K. Kaya, Department of Agricultural Biology, Gyeongsang National University, Jinju 620, Korea and Division of Nematology, University of California, Davis, CA 95616, U.S.A.

The effects of soil environments on the entomogenous nematode, *Heterorhabditis heliothidis*, to infect its insect host were investigated. Five infective nematodes were placed on the soil surface dispersed 8 cm downwards and infected the host within 72 hours. No significant difference in nematode mortality of the insect host was observed between soil with or without roots, and soil sterilized or non-sterilized. Insect mortalities by nematodes were 66.7% at 0 mmhos/cm, 57.8% at 1 mmhos/cm and 46.7% at 3 mmhos/cm, but decreased suddenly from 5 mmhos/cm in salinity study. The ability of nematode to find and infect its insect host was significantly high in raw humus, and sand, loam and clay in turn. The nematode was affected by ammonia gas and inactive over pH 12.

#63

FIELD CAGE STUDIES OF THE SPRING BEHAVIOUR OF THE PLUM CURCULIO, *CONOTRACHELUS NENUPHAR* HERBST (COLEOPTERA: CURCULIONIDAE) IN A SOUTHERN QUEBEC DWARF APPLE ORCHARD, USING A RADIOISOTOPE LABELING TECHNIQUE. G.A. Chouinard, G. Racette, S.B. Hill & C. Vincent, Department of Entomology, Macdonald College of McGill University, Sainte-Anne de Bellevue, Quebec, Canada H9X 1C0.

In spring of 1984 and 1987, two field cages containing 3 to 4 dwarf apple trees were used to monitor plum curculio (PC) foraging behaviour. Ca. 20 PC per cage were individually marked with paint containing ^{65}Zn to allow precise relocation and identification. Within-cage 24 hours surveys were made ca. once a week between full bloom and advanced fruit set. In 1987, movements were also surveyed 2 to 3 times a day from PC emergence to advanced fruit set. Behaviour, substrate occupied and distance from the trunk and from the ground were noted. PC did not climb the trees immediately after emergence, remaining sheltered near the base of trunks and nearby tufts of grass. Massive dispersal from the ground to the trees occurred during pink bud stage and mean observed dispersal activity and height increased continuously to reach a peak at fruit set. PC choice of substrate and behaviour changed with host phenology.

#64

VERTICAL DISTRIBUTION OF APHIDS ON MAIZE. WHY DO THEY CHANGE SITES? D. Coderre, Département des Sciences Biologiques, Université du Québec à Montréal, C.P. 8888, Succ. A, Montréal, Canada H3C 3P8.

Species composition and temporal and vertical distributions of aphids were studied in corn fields of southern Quebec from 1978 to 1986. Sixty corn plants were sampled weekly each year. We identified three aphid species: *Metopolophium dirhodum*, *Rhopalosiphum maidis* and *Rhopalosiphum padi*. *M. dirhodum* was concentrated on leaves close to ground. *R. maidis* and *R. padi* preferred the ear. However aphids showed a significant change in their position on the plants during the course of the season. The quality of the resource, the climatic factors and the impact of the predators were involved in this behaviour.

#65

OF MITES AND MODELS. J.B. Collings*, D.J. Wollkind and M.E. Moody, Department of Applied Mathematics, Washington State University, Pullman, Washington 99164-2930 USA.

A comparison is made between the nonlinear behavior of the Holling-Tanner predator-prey differential equation model system and the Emlen-Bazykin model by means of the computer-aided numerical bifurcation code AUTO 86 with model parameters chosen appropriately for a temperature-dependent mite interaction on fruit trees. This comparison, which is facilitated by noting that the latter model is in fact a first-order approximation to the former one, shows the Holling-Tanner model to be superior for the purpose of reproducing theoretically the periodic population cycles actually observed by Huffaker and his co-workers during their experiments involving the predator-prey interaction between the six-spotted spider mite *Eotetranychus sexmaculatus* Riley and the predacious mite *Metaseiulus occidentalis* Nesbitt on oranges. In particular, this correlation is accomplished by superposing the population densities characteristic of two different subpopulations possessing parameter values consistent with the variability of food quality.

#66

RESEARCH METHODOLOGY TO DETERMINE SORGHUM VARIETAL RESISTANCE TO *Diatraea saccharalis* (FABR., 1794) (LEP.:PYRALIDAE) S.A. De Bortoli*, F.M. Lara, Department of Entomology and Nematology, FCAV-UNESP, Jaboticabal, SP, Brazil, 14870.

The objective of this research was to evaluate some biological aspects of *D. saccharalis* reared in an artificial media containing sorghum genotypes (resistant AF-28, and, susceptible EA-73) in a form of dry and triturated leaves and stalks, and stalks lyophilized extract to test the methodology to determine the varietal resistance.

They were evaluated the weight, period and larval viability; the weight, period and pupal viability; adult longevity; period from larvae to adult; and eggs number/female.

According to the obtained results it was observed that AF-28 genotype in a dry and triturated leaves and stalks as well as in lyophilized stalk extract reduced the larval and pupal weight. The AF-28 genotype in a dry and triturated stalks reduced the eggs number/female and pupal viability.

Supported by FAPESP, CNPq and UNESP.

#67

ELECTROPHYSIOLOGICAL DISCRIMINATION OF SEX PHEROMONE ATTRACTANTS AND INHIBITORS IN THE CABBAGE ARMYWORM, *MAMESTRA BRASSICAE* L. (LEP.:NOCTUIDAE). C.J. Den Otter, Department of Animal Physiology, University of Groningen, The Netherlands.

Electroantennogram recordings revealed that from the 6 substances isolated so far from pheromone glands of *M. brassicae* females, only (Z)-11-hexadecenyl acetate, (Z)-9-hexadecenyl acetate and (Z)-11-heptadecenyl acetate are perceived by the males. This suggests that these substances may be female sex pheromone components. The antennae also respond to (Z)-9-tetradecenyl acetate and (Z)-11-hexadecenol, which are sex attractant constituents of various closely related species, but act as strong attractant inhibitors on *M. brassicae* males.

Single sensillum recordings revealed that volatiles which activate the so-called Type B cells induce avoidance behaviour in the males, whereas substances activating the type C cells evoke sexual behaviour and are attractive. This offers possibilities for rapid electrophysiological determination of substances inducing sexual or avoidance behaviour.

#68

SUSCON – SUCCESS WITH CONTROLLED RELEASE TECHNOLOGY. M. Marsh, Incitel International, Brisbane, Australia.

No Abstract

#69

EFFICACY OF NEEM SEED KERNEL EXTRACT ON THE COWPEA WEEVIL, *CALLOSOPRUCHUS MACULATUS*: Ketki D. Desai & Pankaj K. Hiradhar, Dept. of Biosciences, South Gujarat University, Surat-395 007 INDIA.

The antifeedant property of principles extracted from Neem seed kernel has been sufficiently documented. Current communication is an attempt to evaluate reproductive and developmental potential of Neem Seed Kernel Extract (NSKE) on *C. maculatus* (Fab.). Surface treatment on container or seeds with ethanolic extract dilutions reduced oviposition, hatching and survival. Aqueous dilutions did not affect oviposition and hatching but reduction in emergence was evident. Concentration as low as 10 µg per seed brought about such effect. Last instar larvae and pupae were treated topically with 0.5 µg and 1 µg aqueous formulation of NSKE. Larvae developed till prepupal stage and survived for an extended period compared to control. NSKE treated pupae developed into defective adults with deranged reproductive structures. Structural disruption and size reduction was apparent in ovariole, oocyte and fat bodies.

#70

ECONOMIC IMPLICATIONS OF CONTROLLING THRIPS ON DRY BULB ONIONS IN THE U.S.A. J. V. Edelson, Texas Agricultural Experiment Station, Weslaco, Texas, 78596, U.S.A.

Results of experiments conducted in Texas indicated that thrips feeding on onion foliage will result in reduction of total yield of onion bulbs and that the reduction is in bulb size. Economic analysis of yield, thrips numbers, and cost of controlling thrips resulted in findings indicating that the use of an action threshold of one thrip per plant yields significant increases in producer profits.

#71

PROGRESS IN DEVELOPMENT OF A PEST MANAGEMENT PROGRAM FOR CONTROL OF ROOTWORMS IN FIELD CORN IN EASTERN CANADA. C.R. Ellis*, Department of Environmental Biology, University of Guelph, Guelph, Ontario, Canada N1G 2W1, G. H. Whitfield*, Agriculture Canada, Research Station, Harrow, Ontario, Canada N0R 1G0, T. Hartman, Plant Industry Branch, Ontario Ministry of Agriculture and Food, c/o Crop Science, University of Guelph, Guelph, Ontario, Canada N1G 2W1.

Corn rootworms are a major pest of corn in Ontario, Canada. It is estimated that ca. 50% (0.8 million ha.) of grain corn grown in the province is treated annually with an insecticide for control of rootworms. Northern corn rootworm, *Diabrotica barberi* Smith & Lawrence, was the most prevalent and damaging rootworm during the past two decades but since 1984, the western corn rootworm, *Diabrotica virgifera virgifera* LeConte, has predominated in the southwest area of the province. Although crop rotation is an effective method for control of corn rootworm, many growers, nevertheless plant corn without rotation (continuous corn). Benefits of an application of insecticide to fields of continuous corn in Ontario are not known and historical data on rootworm occurrence and density are not available because of a lack of accurate monitoring techniques and the high cost of obtaining this information.

In 1985, an integrated pest management program for field corn in Ontario was proposed consisting of 2 parts: 1) to monitor various life-stages of rootworm and assess present methods of control of the pest in fields planted to continuous corn; and 2) to investigate new monitoring techniques, determine overwintering survival and hatch of rootworm eggs and assess crop loss in grain corn. Development of this program and progress so far is presented and discussed.

#72

THRIPS AS POTENTIAL VECTORS OF BROWN ROT ON STONEFRUIT. E.C. Ellis*, D.R. Penman and R.E. Gaunt, Plant Protection Group, Lincoln College, Canterbury, New Zealand.

Brown rot (*Monilinia fructicola*) of stonefruit was investigated in connection with the occurrence of thrips (Thysanoptera: Terebrantia) on flowers and fruit. Scanning electron microscope photographs of thrips removed from sporulating flowers and fruit revealed the presence of brown rot spores on their bodies. Further investigations to fully determine thrips potential as vectors of *Monilinia fructicola* are outlined.

#73

BIOLOGY OF *CHLOROPHORUS VARIUS* MULL. (COLEOPTERA: CERAMBYCIDAE). S.I. El-Sherif* and A.W. Tadros, Department of Economic Entomology and Pesticides, Faculty of Agriculture, Cairo University, Giza, Egypt.

In Egypt, the wasp beetle *Chlorophorus varius* Mull. is an economically important pest on grape vine (*Vitis vinifera* L.). Larvae excavate into the stems and branches of vine trees which render feeble and easily broken. The different biological processes and developmental stages of the insect are described. The durations of the immature and mature stages are also determined under laboratory conditions. The egg, larval, pupal and adult stages lasted for 5-8, 309-376, 10-19 and 6-23 days, respectively. The respective durations of the pre-oviposition, oviposition and post-oviposition periods were 4-8, 8-12 and 0-4 days. Female beetles laid 12-54 eggs. The total life-cycle elapsed 329-408 days, with an average of 370.9 ± 6.3 days, thus indicating that *C. varius* has one generation a year.

#74

THE ALFALFA SEED CHALCID *EURYTOMA (BRUCHOPHAGUS) RODDI* GUSSA: A POTENTIAL PEST IN IRAN. Parvaneh Azmayesh Fard, Entomology Department, Faculty of Agriculture, University of Tehran, Karaj -Iran 31584.

The alfalfa seed chalcid occurs in the northern, western and central provinces of Iran. They are more abundant during the first generation, and cause the most damage to seeds produced from the first cut: seeds collected from around the field at the Karaj College experimental farm were heavily infested (80%). Since alfalfa seed is customary produced from the second cut, this may be one of the reasons for low infestation of seeds in this country. This pest overwinters as larvae in seeds scattered in fields anywhere alfalfa seed is kept. Adults emerge in spring when alfalfa is in full bloom and the female lays eggs in the newly developed seeds. They are 3-4 generations per year. Laboratory investigations show that under 28°-30°C and 50-70 percent R.H., the incubation period is 2-4 days, the larval duration is 9-15 days and the nymphal stage lasts 9-12 days.

#75

STUDIES ON THE CARBOHYDRATE COMPOSITION OF BYDV-INFECTED WHEAT AFFECTING THE BIOLOGY OF THE ENGLISH-GRAIN APHID, *SITOBION AVENAE* (F.). A. Fereres*, J.E. Araya, J.E. Foster. Department of Entomology, Purdue University, West Lafayette, INDIANA, 47907, U.S.A.

Sitobion avenae (F.) feeding on BYDV - infected wheat was found - to have a shorter developmental time, a greater fecundity and intrinsic rate of increase (r_m) than on non-infected wheat. In addition, *S. avenae* showed a non-preference type of response to the BYDV-resistant 'Caldwell' wheat, when compared to the BYDV-susceptible 'Abe' wheat. These results suggest that BYDV might improve the nutritional quality of the sap ingested by the aphid, resulting in changes in the life cycle and feeding behaviour of the vector. The non-structural carbohydrate content of BYDV-infected wheat plants at different growth stages was analyzed.

The results indicated that wheat leaves infected with BYDV had a higher content in sucrose than non-infected leaves, suggesting that a higher content of this carbohydrate in the aphid diet might be an explanation for the better performance of *S. avenae* on BYDV-infected wheat.

#76

INFESTATION PATTERN OF FRUIT FLIES (DIPTERA:TEPH RITADAE) ON *Citrus sinensis* OSBECK VAR. PERA IN SÃO PAULO STATE,BRAZIL. O.A.Fernandes*, F.M.Lara; S.A. De Bortoli; M.M.C. Telles. Departamento de Entomologia e Nematologia, UNESP, 14870, Jaboticabal, SP, Brazil.

In 1984/85 forty traps were distributed in four rows in a citrus field. Each trap (Valenciano modified type) contained 100 ml of corn hydrolyzed protein at 1%. The samples of the fruit flies species as well as the infested fruits were weekly studied. During the period were collected 8119 fruit flies, being 95.65% of *Ceratitidis capitata* (Wied.,1824) and 4.35% of the genus *Anastrepha*, with predominance of the *Anastrepha fraterculus* (Wied.,1830).

The incursion of the fruit flies in the orchard increased gradually, being that from the collects of the first to those of the seventh row there was a time equivalent to 30 days. The population peak occurred at the end of July. It was observed a high positive correlation between the collected flies and attacked fruits. For *C. capitata* the fruit shedding occurred at 35-49 days and for *Anastrepha* spp. was at 49-63 days after the flies collectings.

#77

POPULATION DYNAMICS OF THE WESTERN CORN ROOTWORM, *DIABROTICA VIRGIFERA VIRGIFERA* LECONTE (COLEOPTERA: CHRYSOMELIDAE): EFFECTS OF MAIZE PLANTING DATE. J.R. Fisher, USDA-ARS-NPA, Northern Grain Insects Research Laboratory, RR 3, Brookings, SD, USA 57006.

The influence of differential planting dates on the development of immatures, survival to and of the adult stage and the subsequent fecundity and fertility of *Diabrotica virgifera virgifera* was determined using a controlled egg infestation technique. Development of immatures as measured by heat units was not affected by the different treatments. Chronological development as indicated by date of immature occurrence and by the adult emergence pattern from the soil was delayed with progressive planting dates. Late season planting of maize had a deleterious effect on survival to the adult stage. Females that emerged from plots planted on successive dates demonstrated that late planting may cause premature mortality. However, no differences were found among the same treatments for fecundity or fertility.

#78

RESURGENCE OF CITRUS RED MITE, PANONYCHUS CITRI MCGREGOR BY SYNTHETIC PYRETHROIDS APPLICATION ON CITRUS TREES. K.Furuhashi and A.Tatara, Entomological Lab. Shizuoka Citrus Experiment Stn., 2-12-10 Komagoenishi Shimizu-shi, Shizuoka-ken 424, JAPAN

Synthetic pyrethroid started to use for-citrus pest since 1984 and resurgence of citrus red mite (CRM) after pyrethroid application became very serious problem in citrus groves in JAPAN.

Among other pyrethroid inducing resurgence, fenvalerate (FV) was selected for this study. Of the various concentration of FV application tested, higher concentration were active in inducing resurgence. External residue of FV on citrus leaves after application of FV(100ppm) were founded around by 30-40 days, all this while natural enemies such as Oligota flavicornis Boidv. et Laocord. and Scolothrips sp. does not work compared to controls. The instantaneous rate of CRM were compared before and after FV application, and no difference between them. The causes for resurgence was highly influenced by long external residue of fenvalerate(pyrethroids) on citrus leaves.

#79

THE EFFECT OF INSECTICIDES ON DIFFERENT FALL ARMYWORM INSTARS ON SWEET CORN. G.M. Ghidui* and J.T. Andaloro, Rutgers Research and Development Center, R.D. #5, Box 232, Bridgeton, NJ 08302 USA and DuPont Experimental Station, Stine-Haskell Building 215, Elkton Road, Newark, DE 19711 USA.

Toxicity of several rates of fenvalerate and methomyl to 1st, 3rd and 5th instars of the fall armyworm (FAW), Spodoptera frugiperda (J.E. Smith) (Lepidoptera: Noctuidae), were determined in field tests using whorl stage sweet corn. All treatments effectively reduced whorl damage caused by 1st instar FAW as compared to the untreated, but a single application of methomyl (both rates) applied over the whorl was significantly more effective than an application of fenvalerate in reducing whorl damage caused by 3rd and 5th instar FAW. Across all plots, greater whorl damage was caused by 3rd or 5th instar larvae as compared to 1st instar larvae. Results indicate that timing of pesticide application is as important a decision as selection of pesticide for FAW management.

#80

EFFECT OF MAIZE RAYADO FINO VIRUS ON THE REPRODUCTIVE BIOLOGY OF ITS INSECT VECTOR, DALBULUS MAIDIS (HOMOPTERA: CICADELLIDAE). C. Godoy and R. Gámez, Centro de Biología Celular y Molecular, Universidad de Costa Rica.

The maize rayado fino virus (MRFV) multiplies in both maize and its leafhopper vector, Dalbulus species. The principal vector of this virus in the Neotropics is D. maidis (De Long and Wolcott), a maize specialist.

Healthy nymphal stages of D. maidis were exposed to MRFV. There was no effect on the rate of oviposition nor on the maturation of eggs by adults. There was also no significant effect on the number of nymphs reaching the adult stage in the next generation. The absence of effects of MRFV on the reproductive biology of D. maidis as well as the previously observed absence of cytopathological effects suggest a "well-balanced" association between virus and vector.

#81

IMPACT OF SPIDER MITE (ACARI: TETRANYCHIDAE) DISPERSAL FROM ALMONDS ON POPULATION DYNAMICS AND RESISTANCE FREQUENCIES IN NEIGHBORING COTTON. E. E. Grafton-Cardwell, Department of Entomology, University of California, Davis, California, 95616, USA.

In the San Joaquin Valley of California, Tetranychus turkestanii Ugarov and Nikolski, T. urticae Koch, and T. pacificus McGregor are key pests of cotton. In almonds, T. pacificus is the most abundant species. Four sites were intensively sampled to determine the impact of spider mites in almonds on the species, densities, stages, and resistance levels of spider mites in neighboring cotton. In general, almonds were a source of T. pacificus throughout the cotton growing season with the greatest impact during peak periods of spider mite dispersal from almonds. These spider mite outbreaks coincided with periods of almond orchard water stress and also followed applications of repellent acaricides. Aerial dispersal from almonds into cotton increased spider mite densities, altered resistance frequencies, and increased the presence of T. pacificus in the cotton population. However, the sudden influx of spider mites into cotton was not always an economic problem because the other spider mite species were usually well established and cotton acaricide treatments were applied close to the time of dispersal. These results do explain, in part, why pesticide resistance frequencies change within fields during the growing season and why acaricide treatments in cotton do not always provide adequate long-term control of spider mites.

#82

NATURAL PREDATION OF COTTON LEAFWORM LARVAE Alabama argillacea (HUEBNER) (LEPIDOPTERA:NOCTUIDAE). S. Gravena* and H.F. da Cunha, Department of Entomology and Nematology, State University of São Paulo, 14870-Jaboticabal, São Paulo, Brazil, South America.

Natural predation on first instar larvae of the cotton leafworm was studied in cotton fields during 1986. The experiments were conducted in two different cotton fields in Jaboticabal, São Paulo, Brazil. The experimental design was based on paired blocks with two treatments and ten replications. Each treatment was formed by one block of 9,000 square meters into 10 plots of 20x45 m each. One of the treatments was maintained in natural conditions and the other was treated with malathion that was taken as a predator exclusion method. In such plots 4 points of one meter of row with 5 plants per meter were observed. The presence of the arthropod predators in the natural conditions provided a first instar larvae predation of 78.6 and 88.9%, after 24 and 48 hs of exposure, respectively. Two predators per one 1st instar larva per meter of row maintained a level of 3 small larvae/m of row. Several species of arthropod predators and their abundance were listed. The plastic-beat was more efficient than the whole plant visual sampling method, capturing the highest number of the arthropod predators per meter of row.

#83

ECOLOGY OF ENDOPARASITOID ENDAPHIS APHIDIMYZA SHIVPUJE et al. ON SAFFLOWER APHID. P. Grover, Zoology Department, University of Allahabad, Allahabad-211002, India.

Almost a hundred years ago Kieffer (1896) reported the occurrence of an endoparasitoid in the aphid Drepanosiphum platanoides Shrank a pest of Acer pseudoplatanus. This was the first world record of an endoparasitic midge (Cecidomyiidae, : Diptera) which he named Endaphis perfidus. In 1985 occurrence of a similar midge was reported from India by Shivpuje et al, who named it E. aphidimyza.

The black aphid Uroleucon gobonis Matsumura is a serious pest of Safflower grown for oil. It is attacked by the midge E. aphidimyza Shivpuje.

Colonies of aphid U. gobonis was developed on Safflower grown in the field of laboratory and midges were reared from infected aphids and pupae brought from Maharashtra.

Biology of the midge E. aphidimyza was studied and the midges were released on aphid colonies. It was recorded that the parasitoid destroyed 50% population in the field experiments.

#84

DAY AND NIGHT VISUAL COUNTS OF ARTHROPODS ON PADDY PLANTS. S.T.S. Hassan and A.M. Yusof, Jabatan Biologi, 43400 Universiti Pertanian Malaysia, Serdang, Selangor, Malaysia.

Data obtained during one growing season indicated differences in size of day and night populations of arthropods on paddy plants. Direct visual counts yielding mean numbers per hill showed differences were obtained for the pest species; Green Leafhoppers (*Nephotettix* spp.), Stemborers (*Chilo* spp.), Zigzag Leafhopper (*Recilia dorsalis*) and the Rice Whirlmaggot (*Hydrellia* spp.), and for the predators; plant bug *Cyrtorrhinus lividipennis*, ground beetle *Casnoidea interstitialis*, spiders, lady beetle *Micraspis discolor*, tettigoniid *Conocephalus longipennis*, trigoniid *Metioche vittaticollis*, and various species of damselflies and dragonflies. Many arthropods were found in larger numbers during the night.

#85

PLANT EXTRACT MEDIATED FEEDING, DIGESTIVE AND REPRODUCTIVE DERANGEMENT IN THE COCKROACH, *PERIPLANETA AMERICANA*. P.K. HIRADHAR*, U.K. BHANGALE AND A.Y. MAHAJAN. Deptt. of Biosciences, South Gujarat University, Surat, INDIA.

Crude leaf extracts of *Azadirachta indica* A. Juss (neem), *Cymbopogon citratus* DC (lemon-grass) and *Ageratum conyzoides* L. (goat-weed) were alimentally administered to cockroaches. Feeding behaviour assessed through measuring the median-gustato-repellent time (RT50) and the qualitative disturbance in digestive enzymes such as amylase, invertase and protease gave dose-dependent and extract-specific results. Overall reproductive performance was examined through gross and microscopic morphology of the ovaries, and the cerebral neuroendocrine apparatus. Depressed neuroendocrine function and altered ovarian morphology indicated vitellogenic disturbance reflected in persistence of previtellogenic oocytes. Neem extract exposed insects demonstrated maximum adverse effects followed by those treated with goatweed and lemon grass.

#86

SUDDEN OUTBREAK OF THE ARMYWORM, *PSEUDALETIA SEPARATA* WALKER AND ITS MONITORING SYSTEMS IN JAPAN. Kazuo HIRAI, Tohoku National Agricultural Experiment Station, Morioka, 020-01 Japan.

The oriental armyworm, *P. separata* is a serious pest of grain crops and pasture in Asia and Australasia. In Japan, this armyworm outbreaks once every few years, mainly on the side of the sea of Japan. This insect normally overwinters as larvae in west Japan warmer than 2 °C, monthly mean air temperature for January. Invasion of the adults up to northern Japan takes place annually in association with the movement of low air pressure from east China through the sea of Japan to northeast, from mid April to June. To forecast the mass immigration is very important for forecast of larval outbreak. An attempt was made to look for correlations between meteorological factors and armyworm overwintering success, in 1958-87 data, in the hope that this can be used to forecast the immigration year. According to a meteorological phenomenon called "teleconnection", when the winter in west Japan is warm and dry, east China on the same latitude is presumed to have a similar weather condition, which would be good for larval overwintering. In a forecasted mass immigration year by the teleconnection, careful attention should be paid to occurrence and movement of low air pressure from east China to Japan from mid April to June, by looking at daily weather maps. For monitoring of invasion of adults, it is preferable to set a molasses trap on grass pasture over 1 ha in area, which is open to west or south without exposure to strong wind. When over 16 female adults were caught per trap per night, larval outbreak occurred in the pasture. Outbreaks in earlier summer always lead to occurrence toward the end of August in rice, corn, and pasture in wider areas.

#87

THE ROLE OF *SITONA HISPIDULUS* ON GROWTH AND STAND DECLINE OF ALFALFA. A. A. Hower*, K. T. Leath. Departments of Entomology and Plant Pathology, ARS-USDA, Penn State University, University Park, PA 16802.

Sitona hispidulus is a suspect pest of alfalfa growth and stand persistence. *S. hispidulus* were excluded from alfalfa plots using ten 3 x 3 x 1 m cages. Surface area of the alfalfa taproot damaged by *S. hispidulus* larvae was over 5 x greater in the uncaged field plots during the 1st study year. The surface area damaged per taproot in the field plots after 3 years increased to a mean 923 mm². The majority of feeding scars now penetrated into the cortex. Nodule dry weight and ethylene production also decreased in response to larval feeding. Root rot fungi were present on all feeding sites. Alfalfa root type and depth of feeding scar did not affect the incidence of these fungi. *Fusarium oxysporum* was the most common rot organism isolated. During 3 years the incidence of *F. oxysporum* remained similar while that of other fungi increased. *F. oxysporum* now penetrated 3 mm below the feeding scars on 37% of the sites examined. Mean taproot diameter was 6-8 mm. There were no significant differences in percent forage cover or yield after the 1st year of *S. hispidulus* damage. By the 3rd year weeds had increased significantly in the *S. hispidulus* exposed plots. Total crop yield and specifically alfalfa yield per quadrat were significantly greater in the *S. hispidulus* exclusion plots.

#88

APPLES - AN EXPERT SYSTEM FOR ARTHROPOD MANAGEMENT.

L. A. Hull*, E. G. Rajotte, P. H. Heinemann, and A. L. Knight, Department of Entomology, Penn State University, Fruit Research Laboratory, Biglerville, PA, USA 17307.

An expert system for arthropod management in apple orchards has been developed for commercial use. This decision support system assures that pest problems are addressed in an integrated fashion. Features of the expert system include extensive use of graphics, portability to many different types of microcomputers, standardization of format, and electronically delivered updates. Pests and natural enemies included in the system are: apple aphid, codling moth, European red mite, rosy apple aphid, spotted tentiform leafminers, *Stethorus punctum* (LeConte), tufted apple budmoth, and white apple leafhopper.

#89

LIRIOMYZA TRIFOLII /BURGESS/ IN HUNGARY-SOME QUESTIONS OF ITS CONTROL. Z. Illovai^x, Cs. Budai, I. Hatala-Zsellér and P. Szabó, Plant Protection and Agrochemistry Station of Csongrád county, Hódmezővásárhely, P.O. Box 99, 6801-Hungary

Liriomyza trifolii was introduced in Hungary by import gerbera propagating material in 1979-80 and 1985-86. Besides gerbera it also caused problems in greenhouse vegetable crops.

The control can not be solved by the help of traditional insecticides. Even the short-effect preparates are not suitable because of the continuous harvest. There are some new active agents being tested against this pest in gerbera. Adults showed considerable sensitivity to cartap and bensultap. Against larvae besides thiocyclam triazophos and methylparathion gave the best effect. The integrated pest management program can be hindered by the *Liriomyza trifolii* to a great extent therefore together with the quarantine measures sprayings with short-effect radical chemicals and gasification are to be applied.

There is no real possibility for biological control of this pest in Hungary so far.

#90

LAPELLED VINYL FENCE AS A BARRIER AGAINST MITES. M. Inoue, Nara Agricultural experiment Station, Kashihara, Nara 634, JAPAN.

Studies of walking paths of two-spotted spider mites and Kanzawa spider mites (*Tetranychus urticae* and *T. kanzawai*) indicated that lapel on the vinyl fence was effective as a barrier. When lapels were turned at angles of 30° and 45°, mites could not get over the fences. After mites climbed up the fence, they began to walk horizontally along the axes of angles. Two mites-releasing tests also showed that the lapelled fence was useful barrier. Spinach plants which cultivated under the rain shelter were protected from the mite attack by the lapelled fence. And when plant wastes of old strawberry were surrounded by the lapelled vinyl fence, mites couldn't walk away from that wastes to the other plants.

#91

DEVELOPMENT OF SYNTHETIC ATTRACTANT FOR THE ONION AND SEED-CORN FLIES, *HYLEMYA ANTIQUA* AND *H. PLATURA* MEIGEN (DIPTERA: ANTHOMYIDAE). Y. Ishikawa* and Y. Matsumoto, Department of Agrobiolgy, University of Tokyo, Tokyo, Japan 113.

A potent synthetic attractant for the onion and seed-corn flies, *H. antiqua* and *H. platura*, and its long-lived formulation were developed. By the chemical analysis of decomposing onion pulp, which has been shown to have potent attractancy for both the onion and seed-corn flies, 2-phenylethanol and n-valeric acid were found as attractive compounds. The aqueous solution of these two components showed superior attractancy compared to the original material. Since the aqueous attractant is not suitable for the practical use in the field due to its rapid evaporation, a new long-lived formulation of this attractant was sought. As a result, dispensing attractants in a silicon rubber bulb was found suitable to release the attractant at a moderate rate. Although the release rate of attractant from the bulb was observed to decrease slowly, a dispenser containing 2 ml attractant was estimated to keep its initial attractancy at least for 28 days under field conditions. Field trapping tests showed that the attractancy of the new formulation was comparable to that of the aqueous form, and now efforts are being made to incorporate the use of this attractant in pest management of these flies.

#92

COMPARATIVE BIOLOGY OF ACARINE PREDATORS OF THE WESTERN FLOWER THRIPS (*FRANKLINIELLA OCCIDENTALIS*). S.G. Johnson* and S.B. Hill, Department of Entomology, Macdonald College, McGill University, Ste. Anne de Bellevue, Quebec, Canada H9X 1C0.

Consumption of *F. occidentalis* first stage nymphs by gravid females of *Amblyseius cucumeris* and *A. mckenziei* was tested at 30°C. Significantly fewer prey were consumed by *A. mckenziei*. Duration of juvenile lifestages at 30°C of *A. cucumeris* and *A. mckenziei* feeding on freshly killed thrip nymphs was not significantly different.

#93

FORAGING AND PARASITISM BY THE APHELINID WASP, *ENCARSIA FORMOSA* GAHAN, FOR THE GREENHOUSE WHITEFLY, *TRIALEURODES VAPORARIORUM* (WESTWOOD), ON TOMATOES. H. Kajita, Institute of Biological Control, Faculty of Agriculture, Kyushu University, Fukuoka 812, Japan.

The aphelinid wasp, *Encarsia formosa* Gahan, is an important agent for biological control of the greenhouse whitefly, *Trialeurodes vaporariorum* (Westwood). Investigations were made on foraging and parasitism by the parasitoid. When a given number of female parasitoids were released on tomato plants bearing different host densities, an aggregation response of foraging parasitoids and an increase in number of parasitized whiteflies were observed. Direct observations suggested that parasitoids visited frequently and spent longer time at higher host densities. However, the parasitism percentage was negatively density-dependent. The number of parasitized host per parasitoid observed increased rapidly with increasing host densities to an upper asymptote at higher host densities. Such an upper asymptote was reached due probably to longer exposure time and higher superparasitism.

#94

CALIBRATION OF MOTORIZED KNAPSACK SPRAYER FOR DETERMINING OPTIMUM DROPLET PARAMETERS VIS-A-VIS INSECTICIDAL DEPOSIT AT THE TARGET SITES FOR THE CONTROL OF BOLL-WORMS ON COTTON. Harcharan Singh Kalra* and Jai Singh, Department of Entomology, Punjab Agricultural University, Ludhiana 141004, India.

Studies for determining the best calibration of a motorized knapsack sprayer for the ultra low volume application of endosulfan low-volume concentrate for the control of boll-worms revealed that the use of a restrictor giving a discharge of 19 ml/min and blower speed of 4800 rpm proved superior to eight other calibrations. This inference was based on the incidence of various boll-worms, carry over of the pink boll-worm, staining and yield of seed-cotton. The spray spectrum had a volume median diameter of 93 µm with droplet density of 407.2/cm² and insecticidal deposit of 80 ppm on the fruiting-bodies. In the best calibration, the deposits on the fruiting-bodies, leaves and stems were 6.22, 49.55 and 4.50 per cent, respectively. This amounted to a maximum deposit of 60.27 per cent on the plants within 3 metres as compared with 35.13-53.07 per cent in other calibrations.

#95

EFFECT OF JH ON THE PRODUCTION OF THE SEXUAL FORMS IN THE BLUE ALFALFA APHID, *ACYRTHOSIPHON KONDOI* SINJI (HOMOPTERA: APHIDIDAE). K. Kawada* and H. Tsumuki, Institute for Agricultural and Biological Sciences Okayama University, Japan 710.

When reared in the short days (8L16D) at 15°C, apterous *A. kondoi* gave birth to sexual females (oviparae) during their early reproductive period. Topical application of juvenile hormone (JH) to forth instar or adult ovipara-producers influenced on the production of number of parthenogenetic females (viviparae). Multiple times of application induced more parthenogenetic females than that of single time treatment. Effect of precocene II and β-ecdysone on the production of sexual females are also discussed.

#96

BIOLOGICAL CONTROL OF SOYBEAN STINK BUGS BY EGG PARASITOIDS. Atsushi Kikuchi, National Agriculture Research Center, Kannondai, Tsukuba, Ibaraki, 305 Japan.

Stink bugs are important pests in Japanese soybean culture. For the evaluation of egg parasitoids as a control means, eggs of two species of stink bug, the one-banded stink bug, *Piezodorus hybneri* Gmelin (Pentatomidae) and the bean bug, *Riptortus clavatus* Thunberg (Alydidae), were inoculated in a soybean field. 1) One egg parasitoid was recognized in *P. hybneri* and two in *R. clavatus*. 2) *Telenomus* sp. (Scelionidae) was a most effective parasitoid of *P. hybneri* and parasitized the eggs in more than 80% usually. 3) *Gryon japonicum* (Ashmead) (Scelionidae) was a common parasitoid of *R. clavatus* and parasitized eggs in about 70% usually. 4) *Ooencyrtus nezarae* Ishii (Encyrtidae) parasitized eggs of *R. clavatus* but the parasitized rate was low. These good results and the results of complementary tests will be discussed.

#97

INTAR-SPECIFIC DIFFERENTIATION IN THE GREEN CITRUS APHID, *APHIS CITRICOLA* VAN DER GOOT (HOMOPTERA: APHIDIDAE). S. Komazaki, Okitsu Branch, Fruit Tree Research Station, MAFF, Okitsu, Shimizu, Shizuoka, Japan 424-02.

A. citricola attacks many fruit trees such as citrus, pear and apple. Spirea plant has been known to be the primary host of this aphid. In Japan, the overwintering population on citrus was also found. It was observed that overwintering eggs on citrus hatched more than a month later than those on spirea. When sexuales on one overwintering host were crossed with those on the other host, the eggs deposited by the crossed oviparae hatched at the intermediate time between original hatching times on two plants. From these results, it was concluded that populations overwintering on these two winter hosts were differentiated in the time of egg hatch and regarded as different biotypes. This suggests the existence of segregation of life-cycle between two biotypes. In Japan, the citrus overwintering biotype was distributed over the citrus cultivated area except the Ryukyu Islands. Spring alatae of citrus biotype was able to infest citrus but those of spirea biotype was not. One biotype could be discriminated from the other by the electrophoretically detectable esterase banding pattern.

#98

A STUDY OF PUPA OF *DACUS OLEAE* GMELIN (DIPTERA: TEPHRITIDAE) IN LIBYA. N.M. Laias*, and A.A. Ben Saad, Department of Zoology, Faculty of Science, Al Fateh University, and National Bureau for Agricultural Consultation and Studies, respectively, Tripoli, Libya.

The study was carried out in four different ecological locations in the north west of Libya. Cages were randomly set on four directions, and five orientations during the period January - December 1983. The results revealed that larvae of the olive fruit fly *D. oleae* (Gmel.) had pupated inside fallen infested fruits, on the soil surface, among debris, and in the soil. The pupation depth varied with location from 2cm to 6cm with maximum 4cm in the coastal regions and 6cm in the internal and mountain regions. The average number of pupae in all locations was 285/m². The prepupal and pupal stages were subject to predation by Formicids, and Carabids. Both stages were also subject to malformation due to number of factors. A range of 28-50% of the pupa were parasitized by *Opius concolor* (Szépl.). The distribution of pupae in the soil was significantly affected by locations and directions.

#99

TECHNIQUES TO DETERMINE SORGHUM RESISTANCE TO *DIATRAEA SACCHARALIS* (FAB.) AND ITS MECHANISMS. F.M. Lara*, S.A. De Bortoli and A.L. Boiça Júnior, Department of Entomology and Nematology, FCA - UNESP, Jaboticabal, SP, Brazil, 14870.

In the last few years, in Jaboticabal, SP, Brazil, experimental studies have been undertaken to determine the best techniques for measuring sorghum resistance to *Diatraea saccharalis*. Artificial infestations in using nylon screen cages (4.05 m³) were set up for worms and adults. The best results for the variety discrimination in worm trials, were obtained with 3 worms/45 day-old-plant. Oviposition tests showed the best results using 50 adult couples/cage (12-45 and 65-day-old plants). Oviposition trials conducted using lyophilized water extracts of leaves showed good results at 24 and 27°C with 2 females: 3 males/cylindrical oviposition cage (20 cm height x 13 cm diameter). Larval feeding tests of water extracts of lyophilized stem impregnated on filter paper showed a good larval feeding response for 20 day-old larvae, in the susceptible genotype.

#100

STUDIES ON CULTURING *ANASTATUS* SP. (HYMENOPTERA: EUPELMIDAE) WITH ARTIFICIAL HOST EGGS. Liu Zhicheng*, Wang Zhiyong Sun Yiren, Liu Jianfeng and Yang Wuhong, Plant Protection Research Institute, Guangdong Academy of Agricultural Sciences, Guangzhou, China.

Anastatus sp. was successfully cultured with artificial host eggs from 1984-87. Twelve formulations of media composed of 7.5-15% hemolymph from *Bombyx mori*, *Samia cynthia ricini* or *Antheraea pernyi* respectively, have been selected with 74.34-93.4% pupation and 66.5-89.4% adult emergence of the parasitoid. Materials for the egg shell and antiseptics "Yan 1, Yan 2 and Yan 3" were developed. The pot tests and orchard releases in 3 successive years showed that the egg parasitisms of *Tessaratoma papillosa* (Hemiptera: Pentatomidae) by artificial media-cultured *Anastatus* sp. reached 89.12% and 89.45% (1985), 73.86% (1986) to 84.62% (1987).

#101

SEXUAL AND FUNDATRIX-LIKE MORPHS IN ASEXUAL POPULATIONS OF THE PEA APHID, *ACYRTHOSIPHON PISUM* (HOMOPTERA: APHIDIDAE). P.A. MacKay*, R.J. Lamb and M.A. Hughes, Dept. of Entomol. U. of Manitoba, Winnipeg, MB Canada R3T 2N2, Agriculture Canada, Winnipeg, MB Canada R3T 2M9, and Div. of Entomol., CSIRO, P.O. Box 1700, Canberra, A.C.T. 2601, Australia.

Of 53 lines of *Acyrtosiphon pisum* (Harris) from 3 Australian locations, one produced oviparae and one produced males when reared at short photoperiods and low temperatures. We conclude that sexual reproduction is not common among Australian pea aphids. However fundatrix-like aphids with short appendages were collected from field populations in the spring. We conclude that these were not true fundatrices because it is unlikely that they hatched from sexually-produced eggs. Samples of aphids from alfalfa showed that the relative length of appendages increased through the spring and early summer and decreased in the late summer and early autumn. When reared at room temperature and a long photoperiod, the offspring of fundatrix-like aphids had longer appendages than their parents and the length of the appendages increased in succeeding generations. Aphids reared at short photoperiods and low temperatures from before birth had reduced appendages. We conclude that some characteristics of fundatrices can be produced environmentally.

#102

A COMPARISON OF INTEGRATED CONTROL PROGRAMMES INVOLVING APHIDS ON LUCERNE AND PSYLLIDS INFESTING BORONIA. J.L. Madden*, S. Suwanbutr and R. Mensah, Department of Agricultural Science, University of Tasmania, Box 252C, G.P.O., Hobart, Tasmania, Australia, 7001.

In Tasmania, lucerne (*Medicago sativa*) is used for both hay production and grazing, while boronia (*Boronia megastigma*), a native shrub, provides an essential oil much in demand by the flavour and fragrance industry.

The former crop is attacked by a complex of aphids (*Acyrtosiphon kondoi*, *A. pisum* and *Therioaphis trifolii*) and the latter by a psyllid (*Ctenarytaina thysanura*). In both crops severe infestations significantly reduce production.

The pest control programmes which are being investigated involve the selection and use of tolerant cultivars, appropriate and strategic spray schedules and the use of methods which favour survival and performance of parasitoids and predators.

The practicality and potential commercial benefits of the respective programmes will be discussed.

#103

FIELD STUDIES OF WESTERN GRAPELEAF SKELETONIZER (*HARRISINA BRILLIANS*) ON GRAPE IN CENTRAL CALIFORNIA. M.A. Mayse*, W.C. Carr, and K.A. Clausen, Department of Plant Science, California State University, Fresno, CA 93740.

Western grapeleaf skeletonizer (WGLS) research conducted at CSUF (1984-1987) focused upon the following areas: 1) Sex pheromone traps as monitoring tools, 2) Life table studies, and 3) Alternative chemical control options.

1) Pheromone traps, some catching 130 WGLS males per hour, clearly reflected three or four generations each season. Peak trap attractiveness was 0700-1000 hours.

2) Individual cohorts of WGLS larvae were monitored by intensive visual examination (1987) to determine patterns of mortality and key factors.

3) Evaluation of microbial insecticides compared with the standard inorganic cryolite (1986) showed Abamectin effective against WGLS larvae.

#104

CLIMEX: A COMPUTER-BASED SYSTEM FOR PREDICTING THE POTENTIAL DISTRIBUTION AND RELATIVE ABUNDANCE OF INSECTS. G.F. Maywald* and R.W. Sutherst, CSIRO, Division of Entomology, Long Pocket Laboratories, P.M.B. 3, Indooroopilly, Queensland 4068, Australia.

Climatic comparisons are valuable in a range of pure and applied entomological activities, such as ecology, zoogeography, pest management, biological control and quarantine.

A computer-based system for matching climates (CLIMEX) has been developed to meet this need. It uses meteorological data to produce a set of indices describing the response of an insect to climate. Population growth and stress indices are combined into an ecoclimatic index (EI) which is readily interpreted by decision makers. The indices can be used to compare different locations and seasons.

The response of the insect to temperature and moisture is described by parameters, which are adjusted to fit different species. Initial parameter values are refined iteratively by running CLIMEX with meteorological data for locations for which the insects abundance is known. The parameter values which give the best fit to the observed distribution are then used to make predictions about other locations.

#105

PREMIERES DONNEES SUR LA BIOLOGIE DE *SPHAEROCORIS ANNULUS* (HEM. SCUTELLERIDAE). Pierre Mbondji Mbondji, Centre de Recherches Agronomiques de Nkolbisson, IRA, BP. 2067, Yaounde, Cameroun.

Au cours des recherches sur *Antestiopsis lineaticollis* Hémiptère Pentatomide nuisible au caféier arabica dans la région des hauts plateaux de l'Ouest et du Nord-Ouest du Cameroun, nous avons récolté en 1981, un autre Rhynchote de la famille des Scutelleridae associé au caféier arabica et qui a été identifié comme étant *Sphaerocoris annulus*. Ces insectes furent par la suite trouvés sur *Vernonia amygdalina* où ils se nourrissent abondamment et se développent. Les observations entreprises sur la biologie de *S. annulus* ont donné des résultats inédits que l'auteur présente ici.

#106

DEVELOPMENT OF MONITORING SYSTEMS FOR THE CABBAGE SEEDPOD WEEVIL, *CEUTORHYNCHUS ASSIMILIS* PAYKULL (COLEOPTERA: CURCULIONIDAE) IN WINTER RAPESEED. J.P. McCaffrey, Department of Plant, Soil and Entomological Sci., University of Idaho, Moscow, ID, 83843, U.S.A.

The spring flights of the cabbage seedpod weevil (CSPW), *Ceutorhynchus assimilis* Paykull, into winter rapeseed fields in northern Idaho have been monitored using pole-mounted, yellow sticky-traps since 1977. Studies were conducted during 1987 to evaluate pole-mounted yellow and white colored sticky traps and two other trap types: a commercially available yellow sticky board and a yellow non-sticky, impact trap. Two trap locations (field margin and 10 m from field margin) were also evaluated. Finally, all trap catches were correlated to sweep-net samples taken at the field border, 10 m and 20 m into the field.

White pole trap catches were generally lower, but significantly correlated to the yellow pole traps. With the exception of the white pole traps, all trap catches were significantly correlated to all sweep-net samples. Yellow sticky boards and yellow impact trap catches were highly correlated to all pole trap and in-field, sweep-net weevil catches.

#107

THE CAROB MOTH *SPECTROBATES CERATONIAE*, AN IMPORTANT PEST OF POMEGRANATE IN IRAN. Esmail Morteza, Entomology Department, University of Tehran, Karaj, Iran 31584.

Pomegranate (*Punica granatum*) is an important fruit in many parts of Iran, and recently has become an exporting product for the country. The Carob moth, *Spectrobates ceratoniae*, though polyphagous in many parts of the world, is mostly destructive in pomegranate orchards in Iran. It attacks up to 80 percent of the fruit and always carries penicillium and aspergillus spores. Thus the damage is followed by the decaying of the fruits, either on the trees or in storage houses. The socio-economic situation in the country seems to be the main reason for the pest outbreak. Chemical control is not effective for this insect.

#108

AN ATTRACTIVE LURE FOR TRAPPING MALE LEOPARD MOTH *ZEUZERA PYRINA* L. (LEPIDOPTERA: ZEUZERIDAE). Esmaili Morteza, Entomology Department, University of Tehran, Karaj, Iran 31584.

In an investigation of the use of pheromone traps for collecting and evaluating fruit tree pests, it was found that one of the pheromones, made for another pest, attracts *Zeuzera* males and not the target pest. It appears that the insect that the pheromone was made for does not exist in the area. However, the pheromone can be used for *Zeuzera* collection. During the growing seasons of 1985, 1986 and 1987, the pheromone was used for population evaluation of *Zeuzera* in several orchards with different climatic conditions. The emergence period of the moth over 3 years was thus determined. The pheromone proved to be effective in direct control of this pest, by trapping the males and disrupting fecundity. In one of the orchards, the degree of infestation of trees decreased from over 70 percent to less than 5 percent after 3 years of male trapping.

#109

RECENT OUTBREAK OF THE CEREAL SUNN PEST *EURYGASTER INTEGRICEPS* PUTON (SCUTELLERIDAE) IN IRAN. Esmaili Morteza, Entomology Department, University of Tehran, Karaj, Iran 31584.

The cereal sunn pest *Eurygaster integriceps* Puton is the most important pest of cereal crops, particularly wheat and barley, in many parts of Iran. This migratory univoltine pest is most prevalent in the plains adjacent to mountain ranges with sparse vegetation. The area under chemical control for this pest has increased from less than 80,000 hectares in 1976 to 800,000 hectares in 1987. Destruction of natural habitats on hillsides, expansion of dry wheat farming in unsuitable areas, delayed harvesting of crops, inadequacy of spraying efficiency, and destruction of natural enemies in the fields, seem to be among the main reasons for this outbreak.

#111

DEVELOPMENT AND REPRODUCTION OF THE PARASITOID, *CERANISUS BRUI* (VUILLET) (HYMENOPTERA: EULOPHIDAE). T. Murai, Shimane Agri. Expt. Stn., Izumo, Shimane, Japan 693.

Simple rearing method for this parasitoid was devised in my laboratory. Parasitized thrips, *Frankliniella intonsa*, *F. tabaci*, *F. hawaiiensis* and *F. coloratus* were reared by the method of Murai and Ishii (1982) using pine pollen and honey solution (10%). Mass rearing of this parasitoid is practically possible by this method.

Developmental period of egg+larva of this parasitoid was synchronized with development of host thrips and short with increasing temperature. The pupal period of this parasitoid was very long in its life cycle. For example, at 20 °C, the pupal period was about 106 days, whereas the period of egg+larva was 13.5 days. Furthermore, there was large variation in the pupal period. It was observed that this parasitoid produced males in autumn (October), whereas this parasitoid reproduced parthenogenetically in the following generations in the laboratory (thelotoky). The mean fecundity and the mean longevity of female adult at 25°C was 162 eggs and 10.4 days, respectively. Parameters of population increase were calculated. When this parasitoid reproduced parthenogenetically, intrinsic rate of increase (r) at 25°C and 20°C was 0.098 and 0.047, respectively.

#112

BIOLOGICAL CONTROL IN THE MARIANA ISLANDS. D.M. Nafus* and I.H. Schreiner. College of Agriculture and Life Sciences, University of Guam, Mangilao, Guam, U.S.A. 96923.

Biological control efforts started in the Marianas in 1912 and have continued to the present. Biocontrol agents have been introduced to control herbivorous insects, weeds, dung, molluscs, livestock pests, mosquitoes and household pests. In all, 108 species of insects as well as 2 predatory mites, 3 snails, 1 nematode and 3 vertebrates were intentionally introduced to Guam for the purposes of controlling 42 pests species. Of the insect species, 35 established, 48 did not establish and the status of the rest is unknown. Among the pests most successfully controlled by biological agents were *Aleurocanthus spiniferus* (Quaintance), *Aleurothrixus floccosus* (Maskell), *Aspidiotus destructor* Signoret, *Nipaecoccus vastator* (Maskell), *Papilio polites* L., *Pelopidas thrax* (L.), *Spodoptera litura* (F.), and *Brontispa palauensis* (Esaki and Chujo). Two weeds, lantana and *Chromolaena*, have successfully controlled by herbivorous insects. Most attempts at biological control in the Marianas were transfers of species successfully introduced elsewhere. Species which established in Hawaii frequently established on Guam as well. Reasons for failure to establish are varied.

#113

THE SEASONAL HISTORY OF WHITE PEACH SCALE (*PSEUDAULACASPIS PENTAGONA* (TARGIONI)) (HOMOPTERA: DIASPIDIDAE) AND ITS HYMENOPTERAN NATURAL ENEMIES IN NORTH CAROLINA. C.A. Nalepa*, Biological Control Laboratory North Carolina Department of Agriculture, P.O. Box 27647, Raleigh, N.C. 27611, J.R. Meyer, Entomology Dept., North Carolina State University, Raleigh, N.C. 27695-7613, and K.J. Giroux, N.C. Dept. of Agriculture (address above).

Hymenopteran parasitoids and mobile stages (males, crawlers) of white peach scale were monitored biweekly (1986) or weekly (1987) in the field from April to December using emergence traps made from 35mm film canisters. Traps were distributed on infested peach trees at the Horticultural Crops Research Station in Clinton, N.C. Three species of hymenoptera were consistently collected from the traps, the primary parasites *Encarsia berlesii* and *Aphytis proclia*, and the hyperparasite *Marietta carnesi*. All three insects showed seasonal peaks of activity, and these peaks differed in the two years of the study. The peach scale exhibited 3 definite peaks of crawler emergence, but crawlers were present in most collections and a partial 4th generation was observed in both years. Differences in parasite populations between years may reflect their response to cessation of pesticide application in the orchard.

#114

INTRASPECIFIC COMPETITION FOR AN OVIPOSITION SITE BY *DELIA ANTIQUA* MEIG. (DIPTERA: ANTHOMYIIDAE). C.M. Noronha*, S.B. Hill, Dept. of Entomology, Macdonald College of McGill University, Ste. Anne de Bellevue, P.Q., Canada H9X-1C0.

Effects of intra-specific competition on the oviposition and survival of *D. antiqua* (onion maggot) on onions (host plant), cabbage and beans (non-host plants) were studied. Although a major pest of onions, *D. antiqua* has been recorded and reared on non-host crops in the field and lab. Whereas number of eggs laid on onions increased with fly density, the number on non-host plants decreased. Peak oviposition occurred later on cabbage than on beans and onions, probably reflecting its lower preference as a host. Adult mortality increased with increasing fly density.

#115

COEXISTENCE OF *BEMISIA TABACI* (GENNADIUS) AND *TRIALEURODES VAPORARIORUM* (WESTWOOD) ON GREENHOUSE GROWN ORNAMENTALS. R.D. Oetting* and T. Liu, Department of Entomology, University of Georgia, Georgia Experiment Station, Griffin Georgia, USA 30223.

Bemisia tabaci and *T. vaporariorum* are pests of greenhouse grown ornamental plants, especially poinsettia. Both species have similar habits and the spatial distribution on the host is similar. The two species can be differentiated but not in all stages of development. The two species were placed on the same plant in equal numbers and with twice as many of one species. When the two species were placed on the same poinsettia plant the *B. tabaci* displaced the *T. vaporariorum* and was the only species present, even when the population was skewed with more *T. vaporariorum* initially. On other plants the *T. vaporariorum* became the only species present.

#116

RELATIONSHIP OF ESTERASE ZYMOGRAM TO DIAPAUSE ATTRIBUTE AND HOST RANGE IN *PANONYCHUS CITRI* (MCGREGOR) (ACARINA: TETRANYCHIDAE). Mh. Osakabe, Akitsu Branch, Fruit Tree Research Station, MAFF, Akitsu, Hiroshima, 729-24 Japan.

Panonychus citri has 2 strains of non-diapausing and diapausing in Japan. Japanese pear and peach are known as their common hosts. The non-diapausing strain develops on citrus though the diapausing strain can not.

Seventeen populations mainly on Japanese pear in 11 prefectures in Japan were examined developments on citrus leaves and esterase zymograms by electrophoresis. Zymograms were divided into 4 types of I-IV. In 7 populations, percentages in maturity on citrus were higher than 80, and their zymograms were type I, II or III. Eight populations which were lower than 10% maturity showed type IV alone. Other 2 populations showed 23.9 and 11.8% maturity, respectively, and type II, III and IV. These 2 populations each were artificially divided into 2 subpopulations with zymograms, ie. type II and/or III and type IV. Those progeny were separately reared, and were tested their development on citrus. Zymogram types and maturity were closely linked together. Percentages in maturity were below 10 in type IV and higher than 90 in the other.

Populations which develop well on citrus can be decided the non-diapausing strain, and the others are the diapausing strain. Thus, the above results show that I, II and III types are the character of the non-diapausing strain, and the diapausing strain has IV. And even if individuals of the 2 strains coexisted, their diapause attributes can be decided by esterase zymograms.

#117

MASS TRAPPING WITH SEX ATTRACTANTS OF *COSSUS COSSUS* L. (LEPIDOPTERA: COSSIDAE). E. Pasqualini¹, S. Maini¹, C. Malavolta² and P. Baronio¹, (1) Istituto di Entomologia "G. Grandi", Università, Via F. Re, 6, 40126 Bologna; (2) Assessorato Agricoltura Regione Emilia-Romagna, Bologna, Italy.

Mass trapping of *Cossus cossus* has been underway in orchards of Italy's Emilia-Romagna region since 1982. Part of IPM programmes, funded by the Region government, the trials are testing funnel and sticky cylinder and delta traps, the attractant blend Z5-12Ac+Z3-10Ac at 0.8+0.2 mg and 16+8 mg concentrations, respectively, and three dispenser types (the baits were furnished by Istituto "G. Donegani", Novara). The effects of dispenser replacement schedules (15, 30, 60, 120 days) and trap number/ha (2, 10, 15, 20, 30, 40, 100) are also being assessed. To date the decrease rate in the number of captured males has been 35%. In the six years this capture rate has been related to attractant concentration, bait replacement intervals and trap number/ha. It is pointed out that, given advances in trap-dispenser effectiveness, this capture rate is susceptible to improvement. Our findings suggest that the following system be used in future mass-trapping trial programmes: (1) funnel traps (top Ø=30 cm, bottom Ø=5 cm, ht=25 cm) with either hard or soft collector and 4 baffles (20 cm ht to raised lid); (2) sex attractant blend of 8 mg Z5-12Ac + 4 mg Z3 = 10Ac in bimatrix dispenser that releases differentially the two compounds so as to keep their ratio constant over release time; (3) dispenser replacement every 50-60 days; (4) 10 traps per ha, mainly set along orchard border.

#118

EVALUATION OF THE ROLE OF PREDACEOUS ANTS IN THE POPULATION MANAGEMENT OF *PSYLLA PYRICOLA* FOERSTER THROUGH THE USE OF EXCLUSION BARRIERS. G.S. Paulson* and R.D. Akre, Department of Entomology, Washington State University, Pullman, WA, 99164, U.S.A.

In Washington state one of the most damaging orchard pests is the pear psylla, *Psylla pyricola* (Homoptera: Psyllidae). Studies during the summers of 1985-1988 concentrated on determining the role of ants in pear psylla management. Barriers were designed and constructed to prevent ants from foraging in selected trees. Pear psylla populations were significantly higher in pear trees in which ants were prevented from foraging than in trees in which ants were present (T-test, paired comparisons, P 0.001).

#119

EFFECTS OF CEREAL APHID CONTROL ON APHID SPECIFIC PREDATORS IN WINTER WHEAT. H.M. Poehling, Institute of Phytomedicine, University of Hohenheim, Otto-Sander-Straße 5, 7000 Stuttgart 70, West Germany.

From 1983-1987 field studies were performed to investigate side effects of cereal aphid control on different beneficial arthropods in winter wheat. It could be shown that prophylactic spraying immediately before flowering was often to early to prevent a later built up of detrimental aphid populations. In some years an accelerated increase of aphid density in combination with reduced immigration of aphid specific antagonists (Coccinellidae, Syrphidae) could be observed in sprayed plots compared to untreated control areas. When aphicides were applied after the economic threshold was reached the already established aphid predators were eliminated by broad-spectrum insecticides like Parathion or Dimethoat. The initial toxic effects could be reduced for some species by the use of appropriate selective pesticides like Pirimicarb or Fenvalerate. However also after application of selective aphicides very detrimental effects on aphid specific predators occurred caused by the complete elimination of prey. These negative effects could be reduced if insecticide efficiency decreased (lowered dose rates) and small aphid populations remained in the fields. Studies of the development of syrphid and coccinellid larvae in relation to aphid density showed that relative high numbers of these predators could survive and complete their development even with limited food supply.

#120

ARTHROPOD COMMUNITY DEVELOPMENT ON APPLE, *MALUS DOMESTICA* (BORKH.) (ROSACEAE): SPECIES POOL EFFECTS. R.J. Rathman* and J.F. Brunner, Washington State University Tree Fruit Research Center, 1100 North Western Avenue, Wenatchee, Washington 98801.

Investigations were conducted in 1986 and 1987 to examine arthropod community development on 'Red Delicious' apple trees placed within sagebrush and riparian habitats in Washington State. Potted 2-year old trees were used as indicator plants to evaluate community dynamics, including time of arrival, establishment and kinds and abundance of arthropods present.

Trees were sampled at 2-week intervals from May through October via visual observations, plant part removal and CO₂ fumigation. Surrounding species pools were sampled via visual observations, plant part removal and sweep samples.

Arthropods illustrating species pool effects included *Chrysopa* spp. (Neuroptera: Chrysopidae), *Medetera* spp. (Diptera: Dolichopodidae), *Frankliniella occidentalis* (Pergande) (Thysanoptera: Thripidae), *Scaphytopius* spp., & *Edwardsiana rosae* (L.) (Homoptera: Cicadellidae). Results provide evidence for the utility of the species pool perspective in viewing relationships between an agricultural crop and arthropod colonists.

#121

OVIPOSITIONAL PREFERENCE OF THE ALFALFA WEEVIL, *HYPERA POSTICA*, (COLEOPTERA: CURCULIONIDAE). J.L. Reid*, R.C. Berberet, and J.L. Caddel, Department of Entomology, Oklahoma State University, Stillwater, Oklahoma, USA 74078.

The alfalfa weevil is one of the most destructive insects to alfalfa. It is found throughout the United States and with high infestations it causes severe damage when not controlled. Alfalfa dormancy may regulate growth characteristics which could influence weevil infestations. Therefore, the objectives of this study were to determine the extent to which alfalfa dormancy influences egg population densities and to identify the location in the alfalfa stem where oviposition is concentrated.

Dormant, moderately dormant, and nondormant cultivars were selected. Egg populations were estimated from samples collected from December through March. Stems were separated into 3 sections for processing to determine the location where oviposition was concentrated.

Dormant cultivars had significantly lower egg numbers than nondormant ones. Egg lay was concentrated in the middle and top sections of the alfalfa stems.

#122

THE EFFECT OF SELECTED STRIPED CUCUMBER BEETLE, *ACALYMMA VITTATUM*, EGG INFESTATIONS ON WATERMELON. P.E. Rensner*, A.C. York, Dept. of Entomology, Entomology Hall, Purdue University, W. Lafayette, IN 47907.

The striped cucumber beetle (STCB) is a perennial pest of cucurbit plants. Larval feeding occurs on the plant roots and is especially damaging to seedlings.

The objectives of this study were to quantify STCB larval effects on mulched and unmulched seedling watermelon plants, and watermelon varietal response. Zero, 75, or 150 STCB eggs were infested onto watermelon seedlings 3, 9, or 3 & 9 days after transplanting for a total of 7 treatments.

There appeared to be no interaction between mulch and egg treatments. Early season vine length was reduced by the treatment of 150 eggs infested 3 & 9 and 9 days after transplanting. Final season melon weights and numbers were not significantly different over the egg treatments.

All the varieties infested 3 or 3 & 9 days after transplanting had reduced growth and development through harvest. Varieties infested 9 days after transplanting were only slightly affected. Later maturing melons appear to be able to outgrow or recover from early season reductions in plant growth when compared to the quicker maturing varieties. But all the varieties tested had reduced yields when compared to the untreated plants.

#123

CHEMICAL CONTROL OF WIREWORMS (AGRIOTES SPP.) (ELATERIDAE-COLEOPTERA). T. Perju, D.A. Reyes, T. Muntean, G. Funar, Department of Entomology, Agriculture Institute, Cluj, Rumania.

Experiments meant for controlling wireworms pest to maize crops were carried out. The main wireworm species were identified and the efficacy of older products, such as FB 7 and Heptachlor 40 CE, was tested, as well as that of newer ones, i.e. Promet 40 CE and Seedox 80 W, used in soil and seed dressing.

Soil dressings are superior to seed dressings as regards larva mortality; Deltamet 40 CE, FB 7 and Seedox 80 W produce 100% mortality. Dressings with the same products, though efficient in seed, are somewhat less so in soil dressing, in that larva mortality reaches only 92-95,4%. However, both treatments can be taken as 'efficient'.

#124

DEVELOPMENT OF WESTERN FLOWER THRIPS, FRANKLINIELLA OCCIDENTALIS (PERGANDE) (THYSANOPTERA: THRIPIDAE) ON CHRYSANTHEMUM AND THE INFLUENCE OF TOMATO SPOTTED WILT VIRUS. K.L. Robb* and M.P. Parrella, Department of Entomology, University of California, Riverside, California, 92521-0314 USA

Frankliniella occidentalis is a serious pest of many ornamental crops, including chrysanthemums. In addition to aesthetic injury to flowers and foliage, F. occidentalis is a vector of tomato spotted wilt virus. Despite its broad host range, vector capabilities and economic importance, there have been relatively few studies on the life history of F. occidentalis. Furthermore, there have been no studies on the effects of the virus on the behavior and development of this insect.

The development of F. occidentalis was determined on chrysanthemum at constant vs. fluctuating temperatures. Although the developmental rates on chrysanthemum were similar to those reported previously for vegetables, the number of progeny produced was significantly greater. The influence of tomato spotted wilt virus on the developmental rates of F. occidentalis was also determined.

#125

A SIMPLE FIELD TEST FOR EVALUATING THE SUSCEPTIBILITY OF PANDEMIS PYRUSANA KEARFOTT (LEPIDOPTERA: TORTRICIDAE) TO VARIOUS INSECTICIDES. J.C. Rodriguez* and J.F. Brunner, Washington State University, Tree Fruit Research Center, Wenatchee, Washington, U.S.A. 98801.

A procedure using pheromone traps was used during the summer of 1987 in Wenatchee, Washington to test insecticide susceptibility of the Pandemis leafroller moth, a pest of apple. Male moths were attracted to pheromone traps in the field and brought into the laboratory. Traps were removed, and the moths present in them were treated directly with a 1 µl dose of insecticide. Traps were maintained at 60-70% RH and 20°C for 72 hrs. Mortality was recorded daily. Untreated control moths showed 100% survival over the 72 hour period. This assay can be used to determine the efficacy of insecticides and in monitoring possible resistance to such compounds.

#84

DRIFT CONTROL WITH SHROUDED SPRAYERS. R.B. Rogers*, Rogers Engineering Inc., 240-103rd St., Saskatoon, SK, Canada S7N 1X7.

Aerodynamic studies in a wind tunnel showed that simple tent-shaped shrouded spray booms have an air stream racing over the top and a low pressure area behind them. Air and spray drops are drawn from the crop canopy by the low pressure area. Once in that area, eddies flip them up into the air stream. These drops produced a band of drift 1 meter behind and above the shroud. An airfoil was added to the top of the shroud that redirected the air stream coming over the top, down behind the shroud, to fill in the low pressure area, eliminating the uplifting effect, the eddies, and drift. Staggered, slit curtains around the bottom were added to seal the shroud to the crop canopy, and prevent air from going underneath and carrying drops out of the shroud. Field drift evaluations showed that off-target deposits did not increase from the .4% levels as wind speed increased up to 27 km/h.

The nozzles are placed at 30° ahead and have an effective nozzle-to-target distance from 35 to 55 cm. A clear plastic rotameter type flow monitor is used on a research model to monitor individual nozzle performances. Field-size units have an electronic spray pattern monitor that monitors spray pattern integrity. The unit can apply mist-size drops at 10 L/ha when equipped with 800017TC tips and 500 mesh screens, or very large drops at 500 L/ha when equipped with 8005 tips. Sprayers have been built from 75 cm for turf application, 2 m for research plot sprayers, and up to 24 m for field application. The excellent drift control of the shrouded sprayer gives the applicator the practical ability to apply pesticides with mist or fog-size droplets. It also eliminates wind as an application limitation which increases timing accuracy. The application of pesticides with less carrier and smaller drops increases coverage and operational efficiency, which reduces application costs.

#85

BEHAVIOUR AND FIELD DYNAMICS OF THE POTATO LEAFHOPPER, *EMPOASCA FABAE* (HARRIS): THE INFLUENCE OF BEAN AND TOMATO INTERCROPPING. William J. Roltsch¹ and Stuart H. Gage², (1) California State University - Fresno, Crop Center, Fresno, California 93740, USA; (2) Department of Entomology, Michigan State University, E. Lansing, Michigan 48824, USA.

Field studies investigated potato leafhopper abundance on its bean host plant in relation to companion plant (tomato) density, bean canopy density, and host plant quality. Laboratory studies quantified leafhopper movement, feeding and oviposition on bean with the inclusion of tomato and several other companion plant leaves. Potato leafhopper field densities on bean foliage were significantly less in treatments with increasing densities of tomato. Adults did not respond to differences in bean canopy density; however, they did respond positively to bean quality, defined by total foliar nitrogen. In laboratory studies, leafhopper feeding, oviposition, and arrestment varied in accordance to the presence and species of companion plants.

#86

IMPORTANCE DES RAVAGEURS DIRECTS DES POMMERAIES DU QUÉBEC DE 1977 A 1987. M. Roy, Service de recherche en phytotechnie de St-Hyacinthe, 3300, rue Sicotte, C.P. 480, St-Hyacinthe, Québec, Canada J2S 7B8 et C. Vincent*, Station de recherche St-Jean-sur-Richelieu P.O. Box 457, Saint-Jean, Québec, Canada J3B 6Z8.

Un projet pilote sur la lutte dirigée a été mis sur pied en 1977, dans des vergers commerciaux répartis dans les 4 principales régions pomicoles du Québec. Le programme de phytoprotection mis en place s'appuyait sur le dépistage des principaux ravageurs des vergers. Les pomiculteurs étaient avisés des traitements à effectuer ainsi que des meilleurs moments pour effectuer les applications phytosanitaires. Les résultats présentés mettent en évidence l'importance des ravageurs directs pour la période 1977-1987 à partir de l'examen des pommes à la récolte, ainsi que l'efficacité du programme de lutte mis en place.

#87

TOBACCO FLEA BEETLE CONTROL IN ITALY BY CHEMICAL SOIL APPLICATIONS AND SPRAYS. L. Sannino*, A. Balbiani, Istituto Sperimentale per il Tabacco, Sezione per la Biologia e la Difesa Fitosanitaria, 84018 Scafati(SA), Italy.

Three field experiments were carried out in 1987 in two locations for the control of *Epithrix hirtipennis* (Meish.) (Coleoptera: Chrysomelidae) – two in Chieti province on flue-cured tobacco and one in Benevento province on fire-cured tobacco. Nine insecticides were tested, as granular before planting soil applications in the fire-cured and in one of the flue-cured experiments, and eight insecticides as spraying at thirteen days after transplanting in the other flue-cured field. Benfuracarb, Carbosulfan, Phorate, Aldicarb and Terbufos, among the products tested before planting soil applications, provided a significant reduction of the parasite population; Benfuracarb gave the best control. Alphasethrin followed by Deltamethrin and a pyrethroid marked PP321, among the products tested as after planting sprays, showed higher control efficacy. Data on biology and distribution of the parasite in Italy are also reported.

#88

THE BIOLOGY OF *DIADAGMA ARGENTEOPILOSA* CAMERON (HYMENOPTERA: ICHNEUMONIDAE) AN INTERNAL LARVAL PARASITOID OF *SPODOPTERA LITURA* (FAB.). T.V. Sathe, Department of Zoology, Shivaji University, Kolhapur-416 004 India.

Diadegma argenteopilosa Cameron, a solitary, endo-larval parasitoid of *Spodoptera litura* (Fab.) was studied under laboratory conditions (26 ± 1°C and 50% ± R.H.). Its white, slightly curved eggs averaging 0.24 mm X 0.060 mm, had an incubation period of 2-3 days in the hosts body cavity, where the larvae developed. There are 5 instars. The first 2 being caudate and other 3 hymenopteriform. Mature parasitoid larva emerged from the host, killing it and then spun a cocoon. The total developmental time from egg to adult was 18 days. The larval and pupal period lasts for 9 and 6 days respectively. Copulation took place soon after the emergence of either sex. Preoviposition period was less than 24 hrs. Oviposition was accomplished in 1-2 sec. Adult life was longest (av. 15.1 days) with 100% honey and shortest (2 days) without food. 10 mated females had an average adult longevity of 15.1 days, oviposition period 9.00 days and progeny production 62.00 with sex ratio (m:f) 1:1.071. 3 to 4 days old host larvae were most suitable for maximum parasitism.

#89

BEHAVIORAL RESPONSE OF THE TWOSPOTTED SPIDER MITE, *TETRANYCHUS URTICAE*, TO ACARICIDES. D. SCHIFFHAUER* AND R. MIZELL, University of Florida, AREC-Monticello, Route 4 Box 63, Monticello, Florida 32344.

Two populations of twospotted spider mite (TSSM) from commercial ornamental nurseries and one laboratory colony were screened for physiological tolerance and behavioral responses to six acaricides: abamectin, carbophenothion, dicofol, propargite, hexakis, and cyhexatin. Initial bioassays used female TSSM placed inside of stickem rings on treated lima bean leaves. Physiological tolerance to carbophenothion and hexakis was detected; behavioral response was evident with hexakis, carbophenothion, propargite, and cyhexatin. Subsequent behavioral bioassays were conducted which allowed mites to move off of treated leaves. Successful movement off of treated leaves was related to the physiological tolerance levels of TSSM, with the greatest numbers of TSSM escaping compounds to which they were physiologically tolerant. Behavioral response to acaricides in TSSM appears to require a certain level of physiological tolerance before it can be effective as a survival mechanism.

#90

THE MOST IMPORTANT GALL MITE SPECIES AND THEIR NATURAL ENEMIES IN ORCHARDS OF WEST GERMANY. J. Schliesske, ALW, Abt. Pflanzenschutz, D-2084 Rellingen, West Germany.

The economically most important gall mite species on fruit trees and shrubs are *Aculus schlechtendali* (Nal.) on apple, *Phytoptus pyri* Pgst. on pear, *A. fockeui* (Nal. et Trt.) on plum/morello cherry, *P. similis* (Nal.) on damson, *Cecidophyopsis ribis* (Westw.) on black currant and *Acalitus essigi* (Hassan) on blackberry and raspberry. A heavy infestation of these mites nearly always means a reduction of the quality of the harvest and also direct losses. Of the predators observed attacking gall mites, the following are able to suppress developing populations; Thysanoptera: *Haplothrips subtilissimus* (Haliday), *Xylaplothrips fuliginosus* (Schille), Diptera: *Arthrocnodax* sp., *Syrphus* spp., Acari: *Typhlodromus pyri* Scheuten, *T. tiliarum* (Oudem.), *Amblyseius finlandicus* (Oudem.), *A. fallacis* (Garm.), *Zetzellia mali* Ewing. Gall mites are often used as a prey, especially by predatory mites, when other food resources are no longer available.

#91

EVALUATION OF EUROPEAN CORN BORER (LEPIDOPTERA: PYRALIDAE) RESISTANCE IN CHRYSANTHEMUM. P. B. Schultz* and M. A. Coffelt. Department of Entomology, Virginia Polytechnic Institute and State University, Hampton Roads Agricultural Experiment Station, Virginia Beach, VA 23455, USA.

Resistance of 12 yellow and 12 bronze chrysanthemum cultivars to the European corn borer, *Ostrinia nubilalis* (Hubner), was evaluated in laboratory studies. Yellow cultivars 'Freedom', 'Classic', 'Compatriot', and 'Fortune' and bronze cultivar 'Pancho' had significantly lower infestation percentages. In field monitoring of chrysanthemum grown in commercial nurseries, the cultivar 'Fireside Cushion' was significantly lower at both nurseries, with cultivars 'Buckeye', 'Grenadine', and 'Viking' also having significantly lower infestation percentages. A significant positive correlation between infestation levels and stem diameters suggests stem thickness may be an indicator of host plant resistance.

#92

AN IMPROVED PROCEDURE TO MAXIMIZE THE SAMPLE YIELD IN COTTON BENEFICIAL ARTHROPOD SELECTIVITY TESTS. B. Sechser, Agricultural Division, CIBA-GEIGY Ltd., CH-4002 Basel, Switzerland.

Present methods to sample beneficial arthropods in cotton are laborious, and prevent the fine study of collected specimens for taxonomical or mode-of-action studies. A novel approach using a combined drop cloth/suction sampling procedure offers considerable improvements.

The principle of the new method is to shake whole cotton plants from two parallel rows against each other over a plastic sheet placed on the soil between the two rows. The dislodged arthropods are sampled immediately with a modified battery-driven car vacuum cleaner. The collected material is killed and stored for later evaluation in the laboratory. For storage the specimens are dried and can be kept in paper bags for periods up to several months.

The method allows the collection of rather large samples in a relatively short period of time and transfers the cumbersome counting process to the laboratory. By this way the risk is avoided of counting specimens twice or to miss them as it happens under field conditions. It also permits the evaluation of very small developmental stages and in addition the observation of any other than pure biocidal activities such as the molting inhibition caused by growth regulators.

#93

A TOTAL RECOVERY METHOD FOR TESTING THE SELECTIVITY OF PESTICIDES AGAINST BENEFICIAL ARTHROPODS IN ORCHARDS. B. Sechser, Agricultural Division, CIBA-GEIGY Ltd., CH-4002 Basel, Switzerland.

Pest management in deciduous crops requires the application of insecticides selective towards beneficial arthropods, but the degree of selectivity is difficult to test in the field because of the sampling problems presented by the mobility of these beneficial species. For tests in apple orchards, a method was developed to overcome these difficulties. Experimental treatments were carried out by spraying apple trees with test insecticides and checks with water only until run-off. Plastic sheets were mounted on raised frames under the trees to catch the falling arthropods. Samples were collected 24, and sometimes 48 and 72 h after treatment by means of a battery-operated aspirator, and counted. After these collections a dichlorvos spray was applied, having both a knockdown effect and a fumigant action, in order to eliminate and collect the remaining arthropod population. In this way, mortality caused by the experimental sprays could be expressed as a percentage of the total beneficial population.

#94

ENHANCEMENT OF *TRICHOGRAMMA SEMBLIDIS* (AURIV.), AN EGG PARASITE OF *Eupoecilia ambiguella* HB. IN VINEYARDS. C. Sengonca & N. Leisse, Institut fuer Pflanzenkrankheiten der Universitaet Bonn, Nußallee 9, 5300 Bonn 1, FRG.

The egg parasite, *Trichogramma semblidis* (Auriv.) is an important natural control agent of the grape wine moth, *Eupoecilia ambiguella* Hb. in the Ahr valley in the northern wine growing area of West Germany reaching up to 100 % parasitization in the first moth generation. In the present study host eggs from a stock culture were exposed periodically in the vineyard to increase the parasite population and thereby the parasitism in the natural occurring grape wine moth population.

In untreated plots cards with at least 30 moth eggs each were attached to 15 grape stocks every week during the whole season. The parasitization of the exposed eggs and emergence of parasites were noted as well as the parasitism of eggs laid by the natural population.

The highest egg parasitism was found in May/June and following a sharp decrease in population density again in September. A considerable rate of parasitization also appeared in the natural population, thereby reducing the second generation.

#95

EFFICACY OF GAMMA-RAYS IN MODIFYING BEHAVIOURAL TRAITS OF *SPODOPTERA LITURA* (FABR.) AND THEIR EVALUATION IN F-1 GENERATION. R.K. Seth* and S.S. Sehgal, Department of Zoology, University of Delhi, Delhi-110 007, India.

A negative relationship between the age of pupae of *Spodoptera litura* at the time of irradiation and γ -radiosensitivity was exhibited when evaluated in terms of growth, development and reproduction. Protracted growth with morphological deformities in the ensuing adults were quite evident at the dose range tested (2 to 20 krad). Gamma irradiation of pupae caused significant reduction in fecundity, egg-hatch, longevity and mating frequency in the crosses involving treated males.

Moths irradiated with different doses (4 to 25 krad) as 1 to 2 day old adults exhibited a decrease in egg-laying, egg viability and adult longevity. The sterilizing dose had a significant influence on these aspects. Irradiation had a little effect on the mating frequency. Specificity in the diel patterns of certain behavioural traits was studied in normal and treated adults at the sterilizing dose. Asynchrony in the rhythms of feeding, mating and ovipositional behaviours was apparent between treated and normal moths, hence lessening the competitiveness of irradiated insects. This incited us to assess the potential of substerilizing doses, specially on F-1 progeny which exhibited protracted growth and distorted sex ratio. Two main attributes of using substerilizing doses for *S. litura* were ascertained: first, a higher degree of inheritance of sterility in F-1 progeny; second, higher competitiveness.

#96

INTERACTIONS OF INSECT GROWTH SUPPRESSORS ON REPRODUCTION OF *DYSDERCUS CINGULATUS* F. K. Satyana-rayana & Kumuda Sukumar, Entomology Division, Regional Research Laboratory, Hyderabad, India.

Many benzoylphenyl ureas best known for their chitin synthesis inhibition have recently emerged as potent insect reproductive inhibitors. Among these compounds, diflubenzuron was reported to show equal or better activity against certain insect pests. An investigation undertaken against a cotton pest, red cotton bug (*D. cingulatus*) with radiolabelled diflubenzuron and penfluron showed that penfluron possessed superior activity in inducing sterility. The Quantitative analysis of DNA and protein content in viable eggs deposited by normal females, and non-viable eggs deposited by penfluron-treated females, indicated gradual increase proportionate to the incubation period. But in the treated eggs the increase was not as significant as in normal. A notable variation was that inhibition of DNA was more profound than inhibition of protein after treatment. This indicates that penfluron interacts with other biochemical processes too, besides chitin biosynthesis inhibition and this may perhaps be a contributory factor in induction of reproductive inhibition. In cotton bugs, mating behaviour did not show any alteration but gonads presented abnormalities.

#97

INTEGRATED CONTROL OF COTTON PESTS IN THE PUNJAB. A.S. SIDHU, PUNJAB AGRIC. UNIV., LUDHIANA, INDIA

Two dozen species of insects damage cotton crop. Studies on their integrated pest control (IPC) revealed that jassid and bollworms are key pests. All recommended varieties are resistant to jassid which has reduced pesticide use by 63%. Due to their early maturity all the varieties also escape late-season attack of bollworms which is more damaging. Suitable cultural control measures and a number of pesticides have been recommended. Criteria for timing sprays and judicious use of insecticides have been developed. Adoption of IPC has reduced bollworm damage by 38%, increased seed-cotton yield by 27% and better quality produce fetched 5% higher price resulting in 35% increase in net income. Overall lint yield in the State increased from 308-374 kg/ha during 1970-80 to 447,427 and 505 kg during 1984, 1985 and 1986, respectively. The IPC technology proved more useful to small farmers as increase in income was 59-65% among farmers owning upto 4 ha land against 24 and 26% increase in case of farmers cultivating 4-8 and 8-12 ha land, respectively.

#98

ECONOMIC GAINS FROM INSECT-PEST CONTROL IN THE PUNJAB (INDIA). Mandeep Singh, Punjab Agricultural University, Ludhiana 141004, India.

Crops and fruit plants in the Punjab State (India) are attacked by about 200 species of insect pests and mites. Out of these about 2 dozen are of major importance. They can cause a loss of about Rs.12900 millions in various crops. Due to various limitations, farmers are not able to adopt effective control measures in each and every field. Anyway, to save these losses, more than 45 different pesticides valued at about Rs.500 millions are used annually. On the basis of area covered for insect-pest control in the State and the efficacy of various control measures, it is estimated that the adoption of pest-control practices results in a benefit of more than Rs.3360 millions annually to the Punjab farmers.

#99

SEX PHEROMONE TRAPPING AND MANAGEMENT OF THE SWEETPOTATO WEEVIL, *CYLAS FORMICARIUS ELEGANTULUS* (S.) COLEOPTERA: CURCULIONIDAE) IN NORTH CAROLINA. K. A. Sorensen, Dept. of Entomology, North Carolina State University, Raleigh, NC 27695-7626

A cooperative monitoring study was done in N.C. in 1987 and 1988 to detect sweetpotato weevil (SPW) locations and activity period and to evaluate trap design and management tactics. Various traps baited with sex pheromone were compared to standard light traps in an isolated coastal area in southeastern N. C.

SPW infestations were detected in over 12 locations in the Ft. Fisher, Outer Banks area. All SPW infestations were associated with the wild host morning glory. These infestations are geographically removed from the commercial sweet potato growing area. Adults were collected from June 11 through October 12, with peak activity in August. Uni-trap and Boll weevil traps were effective and preliminary studies indicate that 2 pheromone sources appear comparable. Base data on mass trapping obtained will be used in the further development and application of an areawide suppression management program.

#100

FIELD MANAGEMENT OF CERATOPOGONID (DIPTERA) CACAO POLLINATORS TO INCREASE YIELDS. S. de J. Soria, EMBRAPA/CNPV, C.P. 130, 95700 - Bento Gonçalves, RS, Brazil.

This paper is a review of work conducted on methods of managing populations of *Forcipomyia* (Diptera: Ceratopogonidae) species in attempting to increase the level of pollination in cacao farms. It is postulated that yields could be increased by inducing higher levels of pollination through the multiplication and the proper management of the populations of pollinating insects. One of the means of obtaining a higher degree of multiplication of the pollinating insects is to provide adequate breeding conditions. Research has indicated that the layer of leaf litter in cacao plantations resulted the best place for the ceratopogonid insects to reproduce. Other breeding places include such materials as rotten pseudostems of banana. Bromeliads and other epiphytes retaining water also allow the reproduction of these insects in the water filled inter-axillary spaces. It is recommended that efforts be made to maintain and even improve the thickness of the leaf litter.

#101

DIAPAUSE INDUCTION, DEVELOPMENT, AND TERMINATION IN FIELD POPULATIONS OF *AMBLYSSEIUS FALLACIS* (GARMAN) (ACARI: PHYTOSEIIDAE). F. C. Swift* and E. J. Herman, Department of Entomology and Economic Zoology, Rutgers University, New Brunswick, New Jersey, USA 08903.

Oviposition had ceased in the field by the end of October indicating that diapause induction in overwintering females was complete.

Diapause development during fall and winter was assayed by collecting overwintering females from the orchard ground cover and measuring the time to first oviposition at 15°C under one of two photoregimes, either 10:14 or 14:10 LD. The rate of diapause development was greatly influenced by photoperiod, with development being much more rapid in the longer photoperiod. Diapause development was completed in some mites by mid-January, in that by this time some mites were no longer influenced by photoperiod and began ovipositing within 6-9 days in the short photoperiod. From that point on there was a gradual increase in the number of mites in which diapause had been completed. However, some mites remained sensitive to photoperiod through mid-March.

During the last week in March the length of time to first oviposition decreased to 1-4 days, indicating that the predators already had fed in the field and egg development had begun.

#102

INSECT SPECIES RICHNESS AND SIMILARITY IN APPLE ORCHARDS UNDER DIFFERENT MANAGEMENT PRACTICES IN HUNGARY. F. Szent-királyi⁺, F. Kozár, Department of Zoology, Research Institute for Plant Protection of the Hungarian Academy of Sciences, Budapest, P.O.Box 102, H-1525, Hungary.

The arthropod faunas of various apple orchards /from abandoned to intensively treated/ were investigated between 1976-1980 regarding community structure and organization. Insect species richness was more than 300 in the intensively pesticide-treated orchard, while in the untreated one it was around 1000. The total species richness significantly decreased with increasing frequency of pesticide treatments and decreasing diversity of adjacent vegetation. The reduction in species number of apple pests depended on the number of treatments, while the species number of natural enemies mainly depended on the diversity of the surrounding vegetation. The species similarities of insect faunas were low even between apple orchards situated in the same area, ranging between 15 and 40 per cent. The aeromofaunas accounted for more than 50 per cent of the total faunas. This high proportion may be important in the processes of colonization.

#103

TETRASTICHINE (HYMENOPTERA : EULOPHIDAE : TETRASTICHINAE), A NEW LEAF GALL CAUSER ON LITCHI CHINENSIS SONN. (SAPINDACEAE) IN CHANTHABURI PROVINCE OF THAILAND. P. Tangkanasing, C. Lekprayoon and S. Boonkong, Department of Biology, Faculty of Science, Chulalongkorn University, Bangkok 10500, THAILAND.

Four types of leaf galls, caused by a new Tetrastichine (Hymenoptera : Eulophidae : Tetrastichinae) on *Litchi chinensis* Sonn. (Sapindaceae), from the Plant Experimental Station in Chanthaburi Province, were studied monthly by opening at least 300 galls under a stereomicroscope from 1986-1987. Gall types, eggs, larval localised region in the galls, larval and adult morphology, life cycle and parasites were also demonstrated in this research.

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#104

INSEMINATING CAPACITY OF GAMMA-IRRADIATED AND NORMAL MALES OF THE MELON FLY, *DACUS CUCURBITAE* COQUILLET (DIPTERA: TEPHRITIDAE).

Tadashi Teruya, Okinawa Prefectural Agricultural Experiment Station, Sakiyama-cho, Naha 903, Japan.

Young male melon fly, *Dacus cucurbitae*, irradiated with 70 Gy two days before adult emergence and unirradiated males were mated with virgin mature females weekly for 6 weeks. Some of unirradiated males were cohabited with virgin females 21 times during the experiment. Unirradiated males transferred many sperms to most of their partners every mating for more than 13 times during the experiment. Irradiated males transferred many sperms only until the 2nd mating, and most of them transferred very few or no sperm after the 4th mating. The sperm depletion of the irradiated males does not refer to their age but to frequency of mating.

#105

PHEROMONE MEDIATED CODLING MOTH MATING DISRUPTION IN A BRITISH COLUMBIA APPLE ORCHARD. D.R. Thomson*, N.P.D. Angerilli, Agriculture Canada, Research Station, Summerland British Columbia, Canada, V0H 1Z0 and P. Kirsch, Biocontrol Limited, Davis, California, United States of America. 95616

The employment of high concentrations of female codling moth *Laspeyresia pomonella* sex pheromone to disrupt mating and consequently to control larval infestations of fruit was examined in a commercial apple orchard in the Okanagan Valley, British Columbia. Polyethylene release devices containing the pheromone blend were applied to treatment blocks just prior to the first male flight in the early spring. Male codling moth numbers were assessed at weekly intervals using synthetic pheromone traps. Codling moth larval damage was quantified on two occasions by a visual examination of developing fruit. In addition, an experiment was conducted to assess the effects of high concentrations of pheromone on the dispersal activity of laboratory reared males.

Traps in the control block caught significantly more male codling moths and apples sustained higher levels of larval damage than traps or apples in the treatment blocks. Male codling moths released in the middle of control and treatment blocks were only recaptured in control blocks.

#106

NEMATODE TRIALS FOR CORN ROOTWORM CONTROL.

G.S. Thurston*, F.A. Elhag and W.N. Yule, Dept. of Entomology, Macdonald College of McGill University, Ste. Anne de Bellevue, PQ, Canada H9X-1C0.

Several entomogenous nematodes of the genera *Steinernema* and *Heterorhabditis* were assessed for ability to control northern corn rootworm (NCR), *Diabrotica barberi* (Coleoptera: Chrysomelidae), larvae in Quebec cornfields. Laboratory bioassays demonstrated a range of pathogenicities of the nematodes to larval NCR. In field experiments, *S. feltiae* and *S. bibionis* soil treatments caused larval NCR population reductions comparable to the chemical insecticides fonofos and PP993 (a new pyrethroid). In field persistence trials, mobile *S. bibionis* and *H. heliothidis* were found throughout the growing season whereas *S. feltiae* was absent in the latter portion of the summer.

#107

IMPACT OF PESTICIDES FOR TOMATO FRUITWORM (LEPIDOPTERA: NOCTUIDAE) SUPPRESSION ON PHOTOSYNTHESIS, YIELD, AND NONTARGET ARTHROPODS IN STRAWBERRIES. J.T. Trumble, W. Carson*, H. Nakakihara and V. Voth, Department of Entomology, University of California, Riverside, CA 92521.

Effects of several chemicals registered or considered for *Heliothis zea* (Boddie) suppression on strawberries were evaluated for impact on plant physiology, yield, and nontarget arthropods. During a period when *Tetranychus urticae* Koch populations had not reached damaging levels, bifenthrin significantly increased photosynthesis rates and significantly reduced stomatal resistance compared with the untreated control. Bifenthrin treatments produced significantly heavier fruit than the controls on 3 of 8 dates in 1985 and 5 of 11 dates in 1986. Foliage and fruit treated with naled at 1.12 or 1.68 kg (AI)/ha on alternate weeks developed visual symptoms of phytotoxicity, but plants did not produce significantly lighter fruit compared with control plants or exhibit a trend toward reduced photosynthesis. However, application of naled (1.68 kg [AI]/ha) showed a strong trend of fewer fruit in 1985 compared with controls. Repeated applications of methomyl, carbaryl, and permethrin produced only transient effects on photosynthetic activity. Although all chemicals tested provided acceptable levels of aphid control, only bifenthrin and avermectin b₁ reduced *T. urticae* populations to below economic injury levels.

#108

AN ENZYME LINKED IMMUNOSORBENT ASSAY FOR DETECTION OF A CLOSTERVIRUS ASSOCIATED WITH MEALYBUG WILT OF PINEAPPLE. D.E. Ullman*, T.L. German, U. Gundasinghe and R. Ebesu, Departments of Entomology and Plant Pathology, University of Hawaii, Honolulu, Hawaii 96822, USA.

Mealybug wilt of pineapple is a disease that has been of economic importance in Hawaii since 1910. The disease has long been associated with the feeding of mealybugs and was thought to be caused by mealybug salivary toxins. Some more recent evidence suggests that the causal agent may be a pathogen. We will report isolation of a closterovirus from plants with symptoms which was not found in uninfected plants and characterize an enzyme linked immunosorbent assay (ELISA) that has been developed to detect this virus plants. Mealybug transmission of this virus will also be discussed.

#109

THE ROLE OF BEHAVIOURAL-ECOLOGICAL STUDIES IN THE EVALUATION OF *EPIDINOCARSIS LOPEZI* AS BIOLOGICAL CONTROL AGENT AGAINST THE CASSAVA MEALYBUG IN AFRICA. J.J.M. van Alphen, P. Neuenschwander, W.N.O. Hammond and H.R. Herren, Department of Population Biology, University of Leiden, P.O. Box 9516, 2300 RA Leiden, The Netherlands.

We explain how the study of host habitat location, host location, host selection and sex allocation can serve to understand why *E. lopezi* is a successful biological control agent.

#110

THE ROLE OF HOST AND HOST PLANT ODOURS IN THE ATTRACTION OF A PARASITOID, *LEPTOMASTIX DACTYLOPII*, TO THE HABITAT OF ITS HOST, THE CITRUS MEALYBUG, *PLANOCOCCUS CITRI*. J.J.M. van Alphen and Xu Chong Ren, Department of Population Biology, University of Leiden, P.O. Box 9516, 2300 RA Leiden, The Netherlands.

We studied whether *Leptomastix dactylopii* uses olfactory cues to find its hosts. The parasitoid is attracted to the odour of both *Stephanotis* infested with citrus mealybug and *Passiflora* infested with mealybugs. In addition *L. dactylopii* is attracted by an odour emitted from uninfested plant parts of *Stephanotis*, but *Passiflora* does not emit such an odour. These results are discussed in the light of the suitability of both plants as hosts for citrus mealybugs.

#111

SPREAD OF BEET YELLOWING VIRUSES BY THE PEACH-POTATO APHID, *Myzus persicae*, AND THE EFFECTS OF VIRUS INFECTION ON CROP PRODUCTION. W. van der Werf* and D. Peters, Department of Theoretical Production Ecology P.O.B. 430, 6700 AK and Department of Virology, P.O.B. 8045, 6700 EM, Agricultural University, Wageningen, the Netherlands.

To understand the epidemiology and damage effects of yellowing viruses in sugarbeet, it is necessary to know (1) the relation between the numbers of the vector, *Myzus persicae* and virus spread and (2) the relation between virus infection and yield loss. Both relations are strongly affected by the development stage of the crop. Aphids colonizing a crop before canopy closure may establish large populations because they multiply quickly on young plants. In the second part of June, when the plants generally make leaf contact, the apterae may start to disperse and disseminate the virus. The latency period of the virus is shorter when the plants are young and aphids transmit the virus more readily to young plants because they are more acceptable hosts. For these reasons, primary infections in a young crop result in greater spread than those occurring in an old crop.

The only leaves that become systemically-infected with virus are those that emerge after the infection. Photosynthesis in these leaves decreases to zero when they are bright yellow. Photosynthesis is not affected in the older not-infected leaves. Therefore, the damage due to virus infection decreases rapidly with the growth of the plants. With a simulation model it could be demonstrated quantitatively that the impairment of photosynthesis in the yellow leaves is the most important factor responsible for yield reduction.

The reduced risk of spread resulting from primary infections after canopy closure and the limited damage suffered by later-infected plants indicates that increasingly higher numbers of *M. persicae* can be sustained as the plants grow. Viruliferous aphids multiplying and dispersing in the crop before canopy closure may lay the basis of extensive spread. Ladybirds may prevent immigrant aphids from establishing colonies and thus limit virus spread.

#112

A MOBILE, MULTIDISCIPLINARY EXPERT SYSTEMS LABORATORY FOR VEGETABLE IPM DELIVERY. R.S. Vernon*, B.D. Frazer and M. Merkens, Agriculture Canada, Research Station, Vancouver, B.C., Canada V6T 1X2.

Integrated pest management programs for onions, carrots, and potatoes were developed recently by Agriculture Canada for commercial use in the Lower Fraser Valley of B.C. The programs are based on insect monitoring systems developed for the onion maggot, *Delia antiqua* (Meigen), the carrot rust fly, *Psila rosae* (F.) and the tuber flea beetle, *Epitrix tuberis* Gentner. The programs, provided to growers by professional consultants on a fee per hectare basis, have reduced insecticide use by up to 90% in monitored fields. Continued use and acceptance by more growers, however, depends on upgrading IPM to a multidisciplinary level, and making the programs more streamlined for consultants. More efficient multidisciplinary IPM programs using electronic weather recording devices and computer technology are being developed with funds from a 4 year A.R.D.S.A. grant. Manually and electronically collected pest, crop and weather data will be analyzed on-site in a computer equipped van, and comprehensive, expert recommendations generated. Prototype, demonstration IPM software programs provide on-site, field specific advice for onion insect management and potato late blight prediction.

#113

AMBIGUITY OF LEATHERJACKET CONTROL IN UNPREDICTABLE WINTERS. H.J. Vlug, Research Institute for Plant Protection, Binnenhaven 12, P.O. Box 9060, 6700 GW Wageningen, The Netherlands.

In the Netherlands control of leatherjackets is commonly advised in late autumn, based on a threshold level of 150 individuals/m². Application of the present-day used chemicals in spring is not recommended because of the risk of bird toxicity, whereas in mild winters some damage may occur already. Application in late autumn followed by a severe frost-period without snow-cover, however, may result in a decimation of the population so that spraying appears to be useless.

#114

DEVELOPMENT OF LOW IPM TECHNOLOGY FOR COWPEA INSECT PEST IN WEST AFRICA. Aliyageen M. Alghali, Grain Legume Improvement Program, International Institute of Tropical Agriculture, PMB 5320, Ibadan, Nigeria.

Socio-economic observations on cowpea production suggest that cowpea is a secondary crop requiring low inputs to boost its production. Grain yield losses varied 6 to 90% depending on the insect species, and flower thrips was by far the most serious. Three sprays at bud initiation, flowering and podding was optimum and profitable for controlling cowpea pests. This is an improvement on the 4 to 5 sprays currently recommended for cowpeas in this region. Intercropping cowpea with cereals decreased the numbers of some pests, but this was insufficient to offset yield losses. Grain yields for intercropping cowpeas were significantly enhanced with two sprays. An IPM prototype involving cropping systems, optimum spray level, insecticide technology and HPR was tested on farmers' fields and found to be cost effective.

#115

EFFECTS OF COMMUNICATION DISRUPTION USING SYNTHETIC SEX PHEROMONE ON THE BEET ARMYWORM, *SPODOPTERA EXIGUA* (LEPIDOPTERA: NOCTUIDAE), POPULATION IN WELSH ONION FIELDS. S. Wakamura*¹, M. Takai², S. Kozai¹, H. Inoue¹, I. Yamashita², S. Kawahara², and M. Kawamura² (1: Shikoku Nat. Agric. Expt. Stn., Zentsuji, Kagawa, 765 Japan, 2: Kochi Pref. Inst. Agric. Forest Sci., Ino, Kochi, 781-21 Japan)

The beet armyworm, *Spodoptera exigua*, has been become a serious pest of Welsh onion in southwestern Japan. This insect showed extremely high resistance against many insecticides. To reveal the feasibility of communication disruption technique, synthetic sex pheromone, a 7:1 mixture of Z9E12-14:Ac and Z9-14:OH was permeated in the 200-ha field which included 24-ha Welsh onion field for 2 months. Attraction of male moths to sex pheromone traps was completely inhibited throughout the period of treatment. Average density of 1st and 2nd instar larvae in the treated field was reduced to 1% level at the maximum compared to that in the untreated field about 9 km distant. Therefore, we concluded that the communication disruption technique should be a useful tool to control the beet armyworm.

#116

ECONOMIC DAMAGE OF SITONA WEEVIL (COLEOPTERA: CURCULIONIDAE) IN LENTILS AND DEVELOPMENT OF A REARING METHOD. S. Weigand, ICARDA, P.O. Box 5466, Aleppo, Syria.

The pea leaf weevil *Sitona* spp. is a serious pest of lentils in West Asia and North Africa. Among the *Sitona* spp. infesting lentils in this region *Sitona macularius* (marsham) is the most abundant. So far mainly chemical control methods were studied, which however might not be practical for the farmers. In a new approach the delta-toxin of *Bacillus thuringiensis* will be tested against *Sitona* larvae, making the rearing of *Sitona* necessary. The weevils were collected in crop traps from the field and kept in petri dishes. The eggs laid were transferred carefully to lentil plants, inoculated and grown in pots. The effect of temperature, soil mixture and moisture on the development and mortality of the *Sitona* larvae was studied.

#117

PEA LEAF WEEVIL, *SITONA LINEATUS*, IN PEAS: IPM FOR THE PACIFIC NORTHWEST, USA. Livy Williams, III* and L.E. O'Keeffe, Dept. of Plant, Soil and Entomological Sciences, University of Idaho, Moscow, ID 83843 USA.

Integrated pest management for *Sitona lineatus* is based on the life history of the insect, crop phenology, and climatic factors. Winter population estimates made by sampling overwintering sites (perennial legumes) give an indication of adult winter survival rates, and the potential for locally injurious insect levels in the spring. Use of flight traps indicate when *Sitona* initiate migrational flights from overwintering sites to seedling peas. Soil sampling peas at this time will determine *Sitona* numbers. This information, plus estimations of seedling size and defoliation, may indicate the need for chemical control measures. From mid to late season, larvae are present and feeding on root nodules, and may cause damage. Post-harvest discing of fields, especially green pea fields, may kill larvae, pupae, and adults, and therefore reduce subsequent populations. Tactics based on *Sitona* life history and environmental factors offer the most cost-effective use of control measures.

#118

THE OCCURRENCE AND PEST MANAGEMENT OF THE ARMY WORM *LEUCANIA SEPARATA* WALKER (LEPIDOPTERA : NOCTUIDAE) AFTER THE CHANGE OF CULTIVATION SYSTEM Yao Wei*, Shaanxi Institute of Zoology, Xian, Shaan Province, China. Sun Wei-bo, Long County Scientific and Technical Committee, Long County, Shaanxi, China

In order to increase per unit area yield, the double-crop system of interplanting of wheat and maize has been used widely in the western part of Shaanxi Province, China. The infestation by this pest has aggravated districts where the cultivation system has changed. This paper reports the regularity of outbreaks of pest in five types of interplanted fields, its feeding behaviour, the influence to the quality and yield of produce, the various natural factors that regulate the numbers of the pest and the application efficiency of ten pesticides in the field.

And this report also gives the pest management programme.

#119

EFFECT OF GAMMA RADIATION ON THE EGG AND FIRST LARVAL STAGES OF *LIRIOMYZA TRIFOLII* (BURGESS) (DIPTERA: AGROMYZIDAE).

Shoshana Yathom*, R. Padova, Susana Tal and I. Ross, Department of Entomology, Agricultural Research Organization and Soreq Nuclear Research Center, Israel

The effects of various doses of gamma radiation originating from Co^{60} source on the egg and first larval stages of *L. trifolii* were studied. Doses of 1000 Gy applied at the egg stage were lethal, lower doses allowed development of larvae and formation of abnormal deformed pupae, but no emergence of flies. At 50 and 25 Gy few flies did emerge, emergence rate increasing with reduction of radiation dose. When first instar larvae were irradiated death occurred within 24 hours at 1000 Gy, and after 48 hours at 750 Gy, and no pupae were formed. At 250–75 Gy no flies emerged from deformed pupae. At 50 and 25 Gy emergence rates were 2.8% and 33.1% respectively.

#120

CHRYSANTHEMUM CULTIVAR PREFERENCES AND SUITABILITY OF THE BEET ARMYWORM, *SPODOPTERA EXIGUA* (HUBNER) (LEPIDOPTERA: NOCTUIDAE). H.A. Yoshida* and M.P. Parrella, Department of Entomology, University of California, Riverside, CA 92521.

The beet armyworm, *Spodoptera exigua* (Hubner) is a sporadic pest of floriculture crops in southern California. The primary method of control is insecticides however, recent evidence has shown problems with resistance development in this pest. In an attempt to search for alternative control methods and decrease the reliance on insecticides, studies were conducted on the potential use of resistant cultivars. Feeding preferences and host suitability of selected chrysanthemum cultivars on the larval stage of the beet armyworm were investigated in the laboratory. In choice feeding assays, fifth-instar larvae consistently exhibited a distinct cultivar preference. Ovipositional preference studies were also conducted under field conditions to determine the relationship in host preference between the larval and adult stages. Life history studies using selected chrysanthemum cultivars were also conducted to examine host suitability.

#121

A NEW METHOD FOR REARING THE TWO PREDATORS *ORIUS ALBIDEPENNIS* (REUT.) AND *O. LAEVIGATUS* (FIEBER) (HEMIPTERA : ANTHOCORIDAE). Fayed N. Zaki, Plant Protection Lab. National Research Centre, Dokki, Cairo, Egypt.

Larvae of *Phthorimeae operculella* Zell., *Anagasta kuehniella* Zell. and *Tribolium confusum* Duv. were used successfully after paralizing them for rearing the two anthocorid predators *Orius albidepennisi* and *O. laevigatus*. The three hosts were found sufficient for normal duration of the predators and for excess of egg production. The deposition of eggs was clearly raised and the mortality appeared during the nymphal stages of the predators because of the strong twisting and resistance in case of the living host larvae was nearly avoided. The obtained numbers of adult predators were markedly increased by using this method of paralizing host larvae.

#122

OVERWINTERING OF *TRICHOGRAMMA EVANESCENS* WESTM. IN EGYPT (TRICHOGRAMMATIDAE: HYMENOPTERA). Fayed N. Zaki*, K.T. Awadallah, Plant Protection Laboratory, National Research Centre, Dokki, Sh. El-Tahrir, Dokki, Cairo, Egypt.

Eggs of *Anagasta kuehniella* newly parasitized by *Trichogramma evanescens* females were held outdoors in the shade November 20th to emergence of the adult parasites. Blackness of the parasitized eggs was observed after 3 days at an average temperature of 11.3°C. Adult parasitoids appeared after 107 days at an average temperature of 11.1°C, during the period of overwintering. When the temperature increased to an average of 16.6°C for five days, the parasitoids emerged. The photoperiod during the period of overwintering ranged between 9 to 10 hours per day.

#123

INTEGRATED CONTROL OF THE SUCKING PESTS OF COTTON PLANTS, IN EGYPT. E.A.ZANATY¹, MOHSEN S. TADROS² & A. EL-SHERBINI¹. ¹Biol.Dept., Fac.of Education, Tanta Univ., ²&3 Plant Protect.Dept., Fac. of Agric., Tanta Univ., Kafre El-Sheikh, Egypt.

The study aimed to determine the effect of two pesticides, (neoron & sumicidin) on the occurring sucking pests of cotton as immature and mature stages. A release of 20 female adults per plant of the predator, *Amblyseius gossypi*, El-Badry was done after pesticide application for pest management. Results indicated that the sucking flourishing insects were: *Tetranychus cucurbitacearum* Sayed; *Bemisia tabaci*, Genn.; *Aphis gossypii*, Glover and *Empoasca discipiens*, Paoli, and that its numbers were fluctuating during time experiment. The release of the predator at different rates, (5, 10, 15 & 20 adult/plant) without pesticide applications, proved to decrease cotton pests. On the other hand, release of *A.gossypii* after neoron, (acaricide) applications decreased the magnitude of *T.cucurbitacearum*, while after sumicidin, (insecticide) applications, was more effective to control the sucking insects. Sumicidin was found to be more toxic than neoron on the recorded insects.

#124

A SIMULATION MODEL FOR THE POPULATION DYNAMICS OF THE CARROT WEEVIL, *LISTRONOTUS OREGONESIS* (LeGonte). D.X. Zhao*, R.K. Stewart, Department of Entomology, McGill University, P.Q. Canada H9X 1C0.

A simulation model was developed for the population dynamics of the carrot weevil, *Listronotus oregonensis*, in muck soil at the Agricultural Canada Research Station in Ste-clotilde, Quebec. The model includes the mortality rates of eggs, larvae and pupae of the carrot weevil with respect to the different planting dates of carrot (God pak 28); winter mortalities of the adult, the temperature dependent growth of the above mentioned life stages and age dependent oviposition. The influences of the egg parasitoid, *A. sordidatus*, on the mortality rates of carrot weevil eggs at different planting dates were also incorporated into the model.

#125

INFLUENCE OF TEMPERATURE ON THE EXPERIMENTAL POPULATION OF *DACUS CUCURBITAE* COQUILLETT (DIPTERA: TRYPETIDAE). C.Q.Zhou*, P.J.Yang, J.R.Carey, Research Institute of Entomology, Zhongshan University, Guangzhou, China.

This paper presented the influence of constant temperature 19, 22, 25, 28, 30 and 36 °C with relative humidity 80-90 percent and lower temperature on *D. cucurbitae*. The threshold temperature and thermal constant of preadult stages were calculated, life tables were constructed and population parameters were analyzed with demographic method. The results showed that threshold temperature and thermal constant of generation were 10.02 °C and 496.7 degree-day, respectively. 30±0.5 °C was recognized as optimal temperature for population growth. Supercooling point of larva, pupa and adult was -6.88±0.93 °C, -7.38±0.84 °C and -8.32±0.88 °C, respectively.

#126

SIMULATION MODELLING OF THE POPULATION DYNAMICS AND DAMAGE POTENTIAL OF THE ROSE GRAIN APHID, *METOPOLOPHIUM DIRHODUM* (HEMIPTERA: APHIDIDAE). X. Zhou and N. Carter, Department of Entomology and Nematology, Institute of Arable Crops Research, Rothamsted Experimental Station, Harpenden, Herts., AL5 2JQ, England.

The rose grain aphid, *Metopolophium dirhodum*, over-winters mainly as eggs on Rosaceae in England and migrates to cereals in spring. It feeds predominately on the leaves where it can occasionally cause serious yield loss, as in 1979. A systems analysis approach is being used to investigate the population dynamics and damage potential of this species. An interaction matrix was constructed to identify relationships between aphid, host plant, natural enemies and abiotic factors. A computer model was developed, using this information, to simulate aphid population growth and yield loss on winter wheat. The model was validated using data from 1979. The predicted peak density (105/shoot) and its timing (25 July) were similar to those observed (113/shoot, 26 July). The model predicted accurately the yield reduction in the field (15%).

Sensitivity analysis will be used to investigate further the importance of components in the system. Also the effects of simulated insecticide applications on aphid population development will be studied, using the model, to optimise pesticide usage.

#127

THE MECHANISM OF INSECTICIDE RESISTANCE IN THE COTTON APHID, *APHIS GOSSYPII* GLOVER. Y.Q. Sun, G.L. Feng, J.G. Yuan, Y.M. Li and P. Zhu, Institute of Zoology, Academia Sinica, Beijing 100080, China.

The cotton aphid is one of the most serious pests in the cotton areas of northern China. Over the past years, the cotton aphid has developed resistance to organophosphorus insecticides. In order to further understand the cause of aphids resistance to them and look for more effective measure to delay the resistance, it is necessary for us to investigate the pesticide resistance of cotton aphids and its biochemical mechanism. The results indicated that the cotton aphids resistance to organophosphorus insecticides is due to the combination and interaction of many resistant factors, such as decreased penetration, insensitive acetylcholinesterase, activity of monooxygenases and glutathione S-transferase, especially the higher activity of naphthyl-1-yl acetate carboxylesterases was thought to be the most important factor of resistance.

#128

INFLUENCE OF SEASON ON HIERARCHY OF OVIPOSITION PREFERENCES AND DIAPAUSE IN *CICADULIA MBILA* NAUDE (HOMOPTERA: CICADELLIDAE). D.T. Akibo-Betts, Maize Research Program, International Institute of Tropical Agriculture, Oyo Road, P.M.B. 5320, Ibadan, Nigeria.

Highly significant differences were observed amongst the cereals for oviposition (F=14.8, P=0.01), nymphal development (F=19.9, P=0.01) and adult development (F=12.6, P=0.01). Millet and sorghum were the best cereal crops for *C. mbila* production. Amongst the wild hosts *S. homonyma* and *E. indica* were significantly better hosts for oviposition (F=7.6, P=0.05) than *C. dactylon* and highly significantly better for nymphal development (F=23.5, P=0.01) than *C. dactylon*. *S. homonyma* was the best wild host for adult development (F=6.67, P=0.05) when compared with *C. dactylon* and *E. indica*. Selection of an oviposition site by female *C. mbila* was influenced by season. Females laid more eggs on roots in winter than in summer. Eggs laid on roots in winter undergo a diapause.

#129

THE MATING BEHAVIOR OF THE RED BAMBOO BORER,
PURPURICENNUS TEMMINCKII GUERINMENEVILLE.

Fauziah-Abdullah*, K. Tabata and T. Hidaka,
Department of Zoology, Faculty of science, Kyoto
University, Kyoto 606, Japan.

The mating behavior of the red bamboo beetle
Purpuricennus temminckii was observed in the
outdoor cage, glass container and in the wind
tunnel.

Female initiated the sequence by approaching
the male before male's mount occurred. In the wind
tunnel, female was significantly attracted to a
male's bait. Male rowed his antennae on the
female before copulation. After copulation,
before dismounting, male signaled to the female
by biting the female's antennae. A sound was
emitted by the female.

Male-male mount and aggressive behavior were
observed both between males and females.
Aggressive behavior was exhibited by antennal
pushing, biting the antenna and leg.

It is supposed that the female was attracted
to the male by the male sex pheromone.

#132

MAIZE RESISTANCE IN THE MANAGEMENT OF THE STEM BORER
CHILO PARTELLUS. J.K.O. Ampofo, The International Centre of Insect
Physiology and Ecology, P.O. Box 30772, Nairobi, Kenya.

No Abstract

#130

SEASONAL EFFECTS ON SOME BIOLOGICAL FACTORS OF PRAYS
CITRI MILL. (LEPIDOPTERA: HYPONOMEUTIDAE). S.A. El-Dessouki,
S.M. El-Awady and M.A. Abo-Sheaesha, Plant Protection Department,
Agriculture, Al-Azhar University, Nasr City, Cairo, Egypt.

The citrus flower moth, *Prays citri* was reared under laboratory
conditions for one generation per each of the successive four annual
seasons of 1985. The data showed that the pre-oviposition, oviposi-
tion, incubation, larval and pupal periods of the insect were affected
by the seasonal weather factors. The shortest development time oc-
curred in the summer season and therefore it was considered the
preferred time for the insect development. In general, females lived
longer than males. The insect sex ratio was approximately 1:1.

#131

BIOLOGICAL ASPECTS OF THE PREDATORY MITE,
DENDROLAELAPS RASMII NASR AND MERSAL (ACARINA:
DIGAMASELLIDAE) WITH DESCRIPTION OF THE IMMATURE
STAGES. M.M. Abou El-Naga and A. Wahab, Faculty of Agriculture,
Al-Azhar University, Cairo, Egypt.

The life history and feeding habits of the predatory mite,
Dendrolaelaps rasmii Nasr and Mersal and its potential biocontrol of
nematodes and acarid mites are described. The predator seemed to be
able to feed on both the soil nematode, *Rhabditis scanica* Allgen, 1949
and the acarid mite, *Rhizoglyphus* sp. Nematodes were preferred and
accelerated the fecundity of the predator.

BIOSYSTEMATICS OF THE DENDROCTONUS FRONTALIS COMPLEX
 G. M. Lanier SUNY Environ. Science, Syracuse NY USA
 J.P. Hendrichs, J.E. Flores Inst. Tec. Monterrey MEX.
ABSTRACT. The validity of *Dendroctonus frontalis*, *D. brevicornis*, *D. mexicanus*, *D. vitei*, *D. approximatus*, and *D. adjunctus* is supported by breeding, karyology, genitalia, and morphology. Conspecific pairings gave fertile progeny while interspecific pairings produced no larvae. The seminal rods of male genitalia and the karyotypes readily distinguished all species. Concepts of the ecology and distribution of some of these species have previously been confused in the area from Central America to the southwestern United States. *D. frontalis* occurs at elevation of less than 2000 m on coastal-facing slopes of the Mexican Sierra Madre ranges where its key hosts are *Pinus oocarpa* and *P. teocote*. *D. mexicanus* occurs at 1800-2500 m in the central Mexican highlands and semi-arid forests of *P. leiophylla* and *P. montezumae* on the interior slopes of the Sierra Ranges. The known range of *D. vitei* is extended to northeastern Mexico; its key host from Central America northward is *P. pseudostrobus*. *D. frontalis* apparently frequently occurs in association with *D. vitei*, but neither species was in association with *D. mexicanus*. The occurrence of *D. mexicanus* in Central America is not confirmed.

EVOLUTION OF SCOLYTID GALLERY SYSTEMS. L. R. Kirkendall, Zoology Division, Univ. Oslo, Box 1050 Blindern, N-0316 Oslo 3, NORWAY.

Egg gallery systems of phloeophagous scolytids vary in many features, including presence or absence of a nuptial chamber or turning niche, number of egg tunnels, orientation of egg tunnels, degree of boring dust removal, egg niche spacing, egg placement, and presence or absence of 'ventilation' holes. Little thought has been given to explaining this diversity since the 3 papers by Ivar Trägårdh over 50 years ago.

Here, I discuss the evolution of the form of phloeophagous scolytid gallery systems. I review the relationship between host plant and gallery form, and the experiments on cues females use in gallery construction. It is clear that certain hosts dictate gallery orientation: unrelated taxa breeding in *Abies*, for example, make transverse galleries, while congeners in *Pinus* tunnel longitudinally. I propose that a combination of sapwood or inner bark structure and host defensive systems is important in tunnel orientation. The relationship between gallery form and the ratio of body size to phloem thickness is also explored. I discuss briefly a hypothesis for how gallery system form, constrained by host plant features, itself constrains the evolution of mating systems.

REPRODUCTIVE STRATEGIES IN *IPS* TYPOGRAPHUS.

O. Anderbrant, Department of Ecology, Lund University, Ecology Building, S-223 62 Lund, Sweden.

Increasing breeding density in the host tree caused females to lay fewer eggs and abandon the egg galleries earlier (reemerge). However, this ovipositional density response was not strong enough to avoid increasing larval competition with density. The offspring production was not affected by parent sex ratio. A proposed decreased production with harem size due to more intense larval competition was avoided by the beetles by a high degree of establishment of new galleries. There was a large individual variation in the temperature and density dependent reemergence. This variation could not be explained by different beetle size or vigour at the onset of breeding. The survival of reemerging beetles was positively affected by their fat content at reemergence, but inversely related to their residence time with the first brood. The residence time or number of eggs laid in the first brood did not, however, affect the production of a second brood. The second brood was readily established also by single females without a need for additional mating. Thus, the adverse breeding conditions, encountered when hosts are colonized at high density, are partly compensated for by an earlier reemergence followed by a second brood production.

PHYLOGENETIC DIVERGENCE OF SEMIOCHEMICAL COMMUNICATIONS OF *IPS* PINE BARK BEETLES (COLEOPTERA:SCOLYTIDAE).
 J. H. Cane¹* and D. L. Wood², Depts. of Entomology,
¹Auburn Univ., Auburn, Alabama, USA 36849 and ²Univ. California, Berkeley, California, USA 94720.

Pheromonal interactions between *Ips* species can elicit cross-attraction, discrimination, and/or mutual inhibition. Hypotheses invoking ecological causes for such differences are popular. Our field studies mostly involve sibling species of the American Southwest (*Ips confusus*, *hoppingi*, *lecontei*, *paraconfusus*). Their host pines share ecotones of post-glacial antiquity. Our phylogeny for these *Ips* utilize morphometric (JHC) and electrophoretic (Molly Stock, Univ. Idaho) characters. Our field tests assess responses of *Ips* species pairs to each other's pheromones and host-pine kairomones in these ecotonal forests.

Between the sister species *confusus* and *hoppingi*, speciation seems to have preceded divergence in pheromonal communications, as *hoppingi* is equally attracted to both species' pheromones. For sympatric *confusus* and *paraconfusus* populations, divergence is proceeding asymmetrically. Only female *confusus* discern pheromones of this pair. Between phylogenetically distinct *confusus* and *lecontei*, pheromonal discrimination is achieved.

Our results suggest that divergence in semiochemical communications has not precipitated speciation of these *Ips*. Prolonged secondary contact has not reinforced their pheromonal premating barriers. For these *Ips* species, differences in semiochemical premating barriers are explained by gradual evolutionary divergence of an ancestrally-shared system, supporting Lanier's contention that pheromonal cross-attraction precludes broad sympatry of closely-related species.

PHEROMONE PRODUCTION AND RESPONSE GOVERNING ATTACK DYNAMICS IN *Ips typographus*. F. Schlyter and O. Anderbrant, Department of Ecology, Animal ecology, Lund University, Ecology Building, S-223 62 LUND, Sweden.

A rapid onset of pheromone production by the male was shown with Y-tube olfactometer tests and chemical analysis (GC-MS). Field collected males had a peak of the two compounds essential for the attraction of both sexes, 2-methyl-3-buten-2-ol (MB) and cis-verbenol (cV), when males had completed the nuptial chamber. Chemical analysis of aerations of attacking males showed that volatiles are released also by associated microorganisms.

Orientation and landing were affected differently by the two compounds, with MB as the most important for close-range behaviours. Field tests showed that beetles discriminate well between sources of different strength, even at close distances. Both sexes are attracted to strong sources of pheromone, but males are less inclined to land close to the source. Addition of ipsenol, ipsdienol, and verbenone, which are produced in older colonization patches, to MB + cV baits reduces attraction.

The need for a density regulation mechanism, to avoid larval competition, could be filled by switching the attack from old to newly colonized patches/trees: Patches with mated males in later attack phases produces little MB + cV and would receive few new attackers. A numerical model calculates the pheromone signal and predicts the numbers and sex-ratios of the beetles attracted. The model describes the mass attack's first part well (density increase to kill the tree), but not the later part (density limitation and switching of attack). The need for additional data, such as response to inhibitory compounds and spacing on bark, is shown by the model.

USE OF THE AEDEAGOUS IN THE SYSTEMATICS OF THE SCOLYTIDAE (COLEOPTERA), WITH PHYLOGENETIC IMPLICATIONS.

D.E. Bright, Biosystematics Research Centre, Canada Agriculture, Ottawa, Ontario, Canada K1A 0C6.

The male aedeagus of numerous species selected from all tribes of Scolytidae are examined and compared. The use of this structure in systematics of the family is discussed and evolutionary trends are outlined. The use of this structure in establishing the phylogeny of the family is discussed.

RECENT ADVANCES IN KNOWLEDGE OF THE DISTRIBUTION AND CLASSIFICATION OF SCOLYTIDAE (COLEOPTERA). Stephen L. Wood, 332 Life Science Museum, Brigham Young University, Provo, Utah, U. S. A. 84602.

The Scolytidae are geologically much older than had been supposed. Recent discoveries in geographical occurrence and in classification contribute to our understanding of phylogeny and behavior.

SCOLYTID DIVERSITY: KEY TO BIOLOGICAL RIDDLES (COLEOPTERA: SCOLYTIDAE). M. Deyrup, Archbold Biological Station, Box 2057, Lake Placid, Florida 33852, USA.

Some biological questions, especially those relating to presumed adaptations, are best approached by comparative studies of a variety of species. Recently accumulated information on systematics, morphology, behavior, and ecology of scolytids should give new perspectives on important questions, for example: are aggregation pheromones simply cross-attractive sex pheromones? What are adaptive values of sib-mating? What is the functional morphology of different types of gallery architecture? What special characteristics are associated with the small number of host-killing species? What is the significance of frontal and declivital horns, brushes, and spines?

PATTERNS OF BARK AND AMBROSIA BEETLES IN TROPICAL FORESTS R.A. BEAVER, School of Pure and Applied Sciences, University of the South Pacific, Suva, Fiji.

The importance of spatial and temporal scale in studies of patterns of bark and ambrosia beetles, and in explanations of these patterns is stressed. At small temporal and spatial scales, the observed patterns result primarily from the interaction of stochastic processes involving individual behaviour and survival, with short- and middle-term environmental heterogeneity in the formation of suitable habitat units, local weather conditions, etc. At larger spatial scales, more deterministic processes involving resource partitioning, interspecific competition, etc. operating over a longer time scale are more important. Depending on the scale used, the patterns may be considered to indicate non-equilibrium or equilibrium communities. These patterns and processes have been very little studied in tropical forests, but seem to differ in degree rather than in kind from those in temperate forests. Examples are given of the patterns and the processes that produce them.

INTERACTION BETWEEN THE AMBROSIA BEETLE *CORTHYLUS PUNCTATISSIMUS* AND ITS MUTUALISTIC FUNGI. R.A. Roeper, Department of Biology, Alma College, Alma, MI 48801 USA.

The ambrosia beetle, *Corthylus punctatissimus*, infesting maple saplings was collected each month in central Michigan. Its mycangia consists of a pair of tubular structures about 4 mm in length located within the male prothorax. Mycangia were removed, examined microscopically, divided into sections, and cultured on mycological media. *Ambrosiella xylebori* and a yeast, *Pichia* sp, were determined to be the primary mutualistic fungi associated with *C. punctatissimus*. *Pichia* sp dominated the mycangial isolates from winter and spring collected adult male beetles. Pleomorphic hypha elements assumed to be *A. xylebori* were observed but were found to be inviable in culture. In June, prior to the beetle's emergence and infestation of new host saplings, *A. xylebori* began to proliferate in a budding growth form within the mycangia and increased to dominate the viable fungal isolates cultured. As the adult male beetles constructed their gallery systems, *A. xylebori* grew out of the mycangia and was inoculated on walls of the tunnel and egg cradles. *Pichia* sp also was present, but reduced in relative quantity. Both fungi lining in the cradle were consumed by larvae. Nonmutualistic fungi were only rarely observed or isolated from mycangia of inactive adult beetles. Only *Pichia* sp was viable from mycangial isolations made from beetles collected in the late fall months. These observations indicated the changing seasonal conditions within the mycangia regulated the proliferation and viability of the mutualistic fungi.

INTERRELATIONSHIPS AMONG DENDROCTONUS AND IPS BARK BEETLES, THEIR VECTORED FUNGI AND HOST PHYSIOLOGY. D.L. Wood^{*1}, J.R. Parmeter, Jr.², D.L. Dahlsten¹. Departments of ¹Entomological Sciences and ²Plant Pathology, University of California-Berkeley, Berkeley, CA 94720, USA.

Fungi vectored by *D. brevicomis*, *ponderosae* and *valens* were inoculated into ponderosa pine seedlings. Each bark beetle species vectored one pathogenic fungus and one fungus that reduced seedling mortality. Some of these fungi were inoculated into ponderosa pines (10-25 cm dbh) in the central Sierra Nevada of California. To determine the extent of interruption of water flow, logs were cut from inoculated trees and immersed in fast green dye. *Ceratocystis minor* (from *D.b.*), and *Leptographium terebrantis* (from *D.v.*) caused the greatest interruption of water. The size of these lesions was reduced by *C. ips* and *C. nigrocarpa*, respectively. Using *D. brevicomis* as vectors of natural levels of inoculum in a tree mortality test, ponderosa pine with high (>6 atm) oleoresin exudation pressure (o.e.p.) and low (<1.5 atm) o.e.p. were colonized by hand at high (150 females/m²) and low (50 females/m²) attack densities. Logs inoculated with various fungi vectored by *D. brevicomis* were exposed in the field to determine the response of associated fauna including natural enemies.

SCANNING ELECTRON MICROSCOPE OBSERVATIONS ON THE AMBROSIA FUNGI GROWING IN THE GALLERIES WHERE THE LARVAE OF AMBROSIA BEETLES ARE GROWING (COLEOPTERA: SCOLYTIDAE AND PLATYPODIDAE) T. Nakashima*, T. Otomo, Y. Kato, and T. Iizuka, Department of Agricultural Biology, Faculty of Agriculture, Hokkaido University, Sapporo, 060, Japan.

The walls of the galleries of the ambrosia beetles, *Xyleborus seriatus*, *X. attenuatus*, *X. gerumanus*, *X. saxeseni*, *X. ishidae*, *X. validus*, *Trypodendron signatus*, *Scolytus platypus shogun*, *S. daimio*, *S. mikado*, *S. tycon*, *Platypus severini* and *Crossotarsus niponicus*, have been observed by a scanning electron microscope. The types of the fungi growing in the mother galleries, larval, pupal and egg cradles were compared with one another. In total, about 20 species of the fungi, which belong to 9** genera, were observed. Some of the fungi were in the condition of pure culture, especially in the period when the larvae were growing. Each fungus was investigated to determine if it was primary ambrosia fungus. These samples were collected from only one species of the host plant (beech logs, *Fagus crenata* Blume) growing in the same place (southern part of Hokkaido). Nevertheless, each beetle has been associated with different fungi as its primary ambrosia fungi. This fact may depend on the origin of the relationships between the beetles and the fungi. ***Ambrosiella*, *Monilia*, *Endomycopsis*, *Monacrosporium*, *Raffaelea*, *Ceratocystis*, *Candida*, *Pichia*, *Torulopsis*.

ZOOGEOGRAPHY AND MIGRATION OF SCOLYTID SPECIES DURING THE LAST 125,000 YEARS IN NORTH AMERICA. Alan V. Morgan, Quaternary Sciences Institute, Department of Earth Sciences, University of Waterloo, Waterloo, Ontario, N2L 3G1.

Approximately 30 species of scolytids have been recorded as fossils from sites across North America, dating from the last (Sangamon) Interglacial, through ice-free episodes of the Wisconsinan glaciation, and into the present (Holocene) Interglacial. Common scolytids of the boreal forest (Phloeotribus and Polygraphus) are widespread in sites pre-dating and post-dating the last ice advance in the Great Lakes region, and are also known from sites elsewhere on the continent. At least one species (Carphoborus andersoni Swaine) is also recorded in the Great Lakes region from the Sangamon until latest Pleistocene time, although today it is only known from northwestern North America. The presence of certain species at fixed geographic co-ordinates and at known points of time allows statements about refugial areas and permits the reconstruction of zoogeographic movements in response to the fluctuating climates of the last ice age.

CURRENT ISSUES IN THE PEST MANAGEMENT OF SCOLYTID BARK BEETLES. J.P. Vitè, Forstzool. Institut der Universität, 7800 Freiburg, West Germany

Since 1979 commercial attractants and traps are used in Europe against bark beetles affecting Norway spruce en lieu the former trap tree methods. Here the use of traps is understood as an integrated measure of the "saubere Waldwirtschaft" aiming at damage prevention. However, this pest management system bases on the infrastructure of an intensive forest management and appears not applicable in the more extensive forms of forest land use. Therefore, the development of response inhibiting semiochemicals becomes mandatory to allow the reduction of beetle damages in forested areas where mass trapping does not apply such as in mountain and wilderness areas national parks and suburban areas.

THE ROLE OF POPULATION BIOLOGY IN DEVELOPMENT OF MANAGEMENT GUIDELINES TO REDUCE LOSSES FROM THE SPRUCE BEETLE (*DENDROCTONUS RUFIPENNIS*) IN WESTERN CANADA. L. Safranyik, Canadian Forestry Service, Pacific Forestry Centre, 506 W. Burnside Rd., Victoria, B. C., Canada, V8Z 1M5.

The spruce beetle is the most destructive insect of mature spruce (*Picea*) forests in western Canada. Endemic populations exist in wind-felled trees and logging slash, in preference to live trees, but injured, diseased or otherwise stressed trees may also be attacked. Population build-up by the spruce beetle in such host materials is a necessary but not a sufficient condition for an outbreak in living trees: the other necessary condition is increased tree/stand susceptibility. These characteristics of spruce beetle populations point to the following main considerations in developing management guidelines: a) maintenance of stand vigour, age and species diversity; b) assessments of stand susceptibility and outbreak hazard; c) maintenance of high utilization standards, management of logging residue and windfall; d) prompt treatment of infested stands.

CHANGES IN THE QUALITY OF SCOLYTID POPULATIONS: THEIR DETERMINATION AND RELATION TO SCOLYTID OUTBREAKS. T.S. Sahota* and F.G. Peet, Canadian Forestry Service, Pacific Forestry Centre, 506 W. Burnside Rd., Victoria, B.C., Canada V8Z 1M5.

Reproductive capacity and survival capability of the individuals of a population are regarded the two cardinal criteria of population quality. Changes in these criteria, and thus in population quality of scolytids are produced by the action of a variety of biotic and abiotic factors. Our progress in detecting these changes, early in the life of the population members is briefly traced. Our current approach is based on the study of chromatin distribution patterns in cell samples. The use of computer-assisted microphotometry and analysis of digitized nuclear images, as used in this approach, is described and utilized for detecting changes in chromatin distribution patterns.

The relationship between chromatin distribution patterns and cell functions on one side and between these pattern changes and population quality changes, on the other, is presented. It is concluded that significant fluctuations in scolytid populations result from changes in population quality which may be detectable, using chromatin distribution analysis, at earlier times than has been possible using other techniques.

DYNAMICS OF TREE ATTACK IN THE BARK BEETLE *IPS TYPOGRAPHUS* UNDER SEMI-EPIDEMIC CONDITIONS. O. Anderbrant*, F. Schlyter and J. Löfqvist, Department of Ecology, Lund University, Ecology Building, S-223 62 Lund, Sweden.

Natural attack dynamics of *Ips typographus* were monitored by landing traps and marking of attacks on Norway spruce, *Picea abies*. 60 out of 110 monitored trees were attacked, most of them at low attack densities (1-3 per dm²). On trees that were "mass attacked" about half of the attacks occurred within 2 days. Switching of attack focus was observed in several cases between adjacent trees, but also trees far from earlier colonized trees were attacked. In general, the sex-ratio of the landing beetle did not change during the colonization period, but at one site female proportion increased after the first period of attack. The landing rates were consistently higher than corresponding rates of new attacks, indicating that a large fraction (80%) left the tree after landing. Landing rates were standardized in relation to catches in pheromone monitoring traps. The pheromone signal from the tree, calculated by an earlier described model, was not correlated with relative landing rates. The calculated pheromone signal could not explain the tree switching that occurred. The inadequacy of the model indicates gaps in the knowledge of pheromone release and behavioural mechanisms.

ATTACK DENSITY REGULATION IN *Ips typographus*: NATURAL MECHANISMS AND MANIPULATION FOR MANAGEMENT. F. Schlyter, Department of Ecology, Animal ecology, Lund University, Ecology Building, S-223 62 LUND, Sweden.

The spruce bark beetle faces two needs for density regulation. A positive regulation, to overcome host resistance, is known to be driven by the aggregation pheromone during the mass attack. A negative regulation, to avoid larval competition, leading to a switching of attack to nearby trees may depend on both a quantitative drop in pheromone signal, spacing behaviours on bark, and production of inhibitors.

Two oxygenated monoterpenes, ipsenol and verbenone, produced later during the attack, have been shown in trapping experiments to inhibit response to synthetic pheromone. Their importance in limiting attack densities were tested in two field experiments with logs baited with synthetic pheromone. In the first, ipsenol and verbenone were combined at a low dose, either as a single point source or with dispensers spread over the log surface, but these treatments did not decrease the numbers of attacks. The second test, with verbenone alone at three different doses applied over the surface in dispensers, showed a strong log-linear dose response, with close to zero attacks at the highest dose.

We do not yet know the importance of and the exact mechanisms for each factor involved in attack density regulation, but one chemical factor proven active here is the release of verbenone. The response of the beetles to this compound is highly dose dependent. Thus, it shows promise for practical management by prevention of attacks. The importance of this chemical signal in the natural setting remains an object for further quantitative studies.

ATTACK AND REPRODUCTION OF BARK BEETLES IN WIND-BLOWN PINE IN NORTHERN FINLAND. H. Saarenmaa, The Finnish Forest Research Institute, Unioninkatu 40A, 00170 Helsinki, Finland.

The material comprised 357 uprooted Scots pines that were felled by autumn storms at four localities in Lapland. A total of 13 phloem-consuming insect species were observed, but only *Tomicus piniperda* occurred regularly. In the first summer after the storm, its attack was successful in 15% of the trees, partially successful in 15%, failed in 35%, and 35% of the trees were not tested at all. In the second summer, the figures were 60%, 5%, 20% and 15%, respectively. The attack pattern of *T. piniperda* was random; it could not distinguish weak trees from strong ones - hence the large proportion of failures. Its ratio of increase averaged 1.7 in the first and 1.2 in the second year after the storm. A strong co-operative increase and a weak competition decrease in the reproduction in relation to attack density could be observed.

HOST RESISTANCE AND ITS UTILITY FOR CONTROLLING SOUTHERN PINE BEETLE IN NORTH CAROLINA. F. P. Hain* and S. P. Cook, Department of Entomology, Box 7626, Grinnells Lab, North Carolina State University, Raleigh, North Carolina 27695.

Research has focused on the mechanisms of resistance to southern pine beetle attack, *Dendroctonus frontalis* Zimm., by loblolly, *Pinus taeda* L., and shortleaf, *P. echinata* Mill., pines. These findings are updated and reviewed. Understanding resistance mechanisms is discussed in terms of its relevance to maintaining the *D. frontalis* population at a low equilibrium state. Measuring host resistance parameters may aid in our understanding of the distribution and accumulation of susceptible host type in areas subjected to frequent beetle outbreaks. It should also aid in evaluating various cultural practices aimed at reducing susceptibility.

MOISTURE STRESS, TREE SUITABILITY, AND SOUTHERN PINE BEETLE POPULATION DYNAMICS. T.D. Paine*, Department of Entomology, University of California, Riverside, California, USA 92521; R.G. Cates, Chemical Ecology Laboratory, Department of Botany and Range Science, Brigham Young University, Provo, Utah USA 84602; F.M. Stephen, Department of Entomology, University of Arkansas, Fayetteville, Arkansas, USA 72701

Loblolly pines inoculated with blue-staining *Ceratocystis* minor, a fungus often associated with the external surface of *Dendroctonus frontalis*, respond by producing a resin soaked hypersensitive-like lesion around the inoculation site. There were no significant differences in the response of loblolly pine at three different heights or across an eight-fold range of inoculum dose. Overtopped trees produced smaller responses than dominant or codominant trees of the same age on a uniform site. There were no differences in tree response to either mycangial fungus or to sterile wounding. Trees did not produce a visible response to *C. minor* during the first 60 hours following inoculation, but produced a response during the next 12 hours that was significantly larger than the response to the other fungi or wounding alone. Females forced to colonize this induced tissue had lower oviposition rates, constructed less gallery and the progeny had higher levels of mortality when compared to beetles in non-induced tissue. These results suggest that host defenses in healthy vigorous trees can influence bark beetle population dynamics.

INFLUENCE OF TREE RESISTANCE ON SOUTHERN PINE BEETLE POPULATION DYNAMICS. F. M. Stephen*, M. P. Lih, T. D. Paine and G. W. Wallis, Department of Entomology, University of Arkansas, Fayetteville, AR 72701.

Mature loblolly pine, *Pinus taeda* L., were frozen near the base of the stem, beneath a dry ice collar, to interfere with normal mechanisms of tree resistance to bark beetle attack, i.e. the primary resin system and the secondary hypersensitive response. The frozen trees and highly similar untreated controls were intensively sampled following pheromone-induced mass attack by southern pine beetle, *Dendroctonus frontalis* Zimm., in order to evaluate the impact of the trees' resistance mechanisms on the processes of beetle attack and reproduction. Extreme variability in response among the frozen trees and between the paired treatment and controls were detected. In general southern pine beetle attack and egg density are greater in trees with minimum resistance, but other population variables are not as clearly affected.

SCOTS PINE RESISTANCE AGAINST *TOMICUS PINIPERDA* AS RELATED TO TREE VITALITY AND ATTACK DENSITY. B. Långström* and C. Hellqvist, Section for Forest Entomology, Swedish University of Agricultural Sciences, S-770 73 Garpenberg, Sweden.

Field observations in areas with high population levels of *Tomicus piniperda* (L.) (Col., Scolytidae) revealed that only the most suppressed Scots pine (*Pinus sylvestris*) trees were successfully colonized by the pine shoot beetles. The attack pattern and colonization success was studied in a high- and low-vigour pine stand, respectively, in Central Sweden. Spontaneous beetle attacks were induced by baiting experimental trees pruned to different crown sizes with fresh pine billets prior to spring flight of the beetles. All baited trees were attacked but successful colonization occurred only in the heavily pruned trees in the low-vigour stand. Attack levels ranged from zero (for unbaited control trees) to more than 800 egg galleries per m² bark surface for unsuccessfully attacked trees. Gallery lengths were inversely related to tree vigour, and the secondary wound reaction was highly variable and difficult to relate to tree vigour. It was concluded that the beetles' shoot-pruning per se cannot predispose host trees for later breeding, and that the physiological mechanisms underlying the resistance of Scots pine to bark beetle attacks are poorly understood.

EXPLORING THE VARIABILITY IN THE HOSTS PERFORMED DEFENSIVE SYSTEM AND IMPACT ON MANAGEMENT PRACTICES. T.E. Nebeker* and J.D. Hodges, Departments of Entomology and Forestry, Mississippi State University, Mississippi State, MS 39762.

Parameters of primary interest associated with the performed defensive system under investigation are resin duct density (vertical and horizontal (radial)) in the xylem, resin flow rate, total flow, and relative viscosity. These parameters as well as numerous tree attributes where measured on half-sib and full-sib families of loblolly pine (*Pinus taeda* L.). The variation in these parameters within- and between-tree has been examined and compared with "woods run" material (genetic history unknown) and full- and half-sib families at 3 locations in the southeastern U.S.

Selection of families for propagation without a knowledge of their potential susceptibility to bark beetle attack has received a low priority for many years. This may have been due to the lack of knowledge concerning parameters that may be useful in identifying resistant families. Findings presented here, although preliminary, are encouraging in that it may be possible for the incorporation of potential bark resistance information into tree improvement programs to meet the needs of the future.

CHALLENGES IN IMPLEMENTING AMBROSIA BEETLE PEST MANAGEMENT PROGRAMS IN BRITISH COLUMBIA. J.A. McLean* and E. Stokkink, Department of Forest Sciences, University of British Columbia, Vancouver, B.C., Canada V6T 1W5 and Phero Tech Inc, 1140 Clark Drive, Vancouver, B.C., Canada V5L 3K3.

Extensive pheromone-based trapping programs throughout British Columbia indicate chronic ambrosia beetle infestations around most sawmills, booming grounds and dryland sorting areas. Recent surveys of active logging areas show that ambrosia beetles are thriving in recently felled logs in logging areas and in logs felled prior to road building. Beetles are being transported with the logs through the system. Ambrosia beetles cause significant reductions in the value of lumber products produced from these logs. Examples of the economic losses will be presented and the challenges in implementing ambrosia beetle pest management programs will be discussed.

SUPPRESSION OF AN *IPS PERTURBATUS* OUTBREAK IN INTERIOR ALASKA USING INTEGRATED CONTROL. R.A. Werner, Institute of Northern Forestry, USDA Forest Service, Fairbanks, Alaska, USA 99775.

Ips perturbatus populations were reduced in upland white spruce, *Picea glauca*, stands in interior Alaska by pheromone-baited trap trees. Felled white spruce trees baited with Ipsdienol caught significantly more adult beetles than felled unbaited trees. Conventional trap trees are living, large diameter spruce which are felled to attract *Ips* beetles. Trap trees felled at 200-foot intervals in a recently logged clearcut caught significantly more *Ips* beetles than decks of 12 trees at 400-foot intervals because competition with spruce beetles, *Dendroctonus rufipennis*, was present in the decked logs but not in the single felled trees.

Pheromone-baited standing trap trees which were frilled at the base were effective in preventing attack by *Ips* beetles in adjacent live trees and protected the fringe or marginal areas of the clearcut from infestation.

THE PLACE OF PARTIAL CUTTING LODGEPOLE PINE IN INTEGRATED MANAGEMENT OF MOUNTAIN PINE BEETLE. M.D. McGregor, 1916 35th Street, Missoula, Montana 59801, U.S.A.

Partial cutting prescriptions were applied in the fall of 1978 through the early winter of 1980 to lodgepole pine stands (*Pinus contorta* Douglas Var. *latifolia* Engelm.) threatened by mountain pine beetle, (*Dendroctonus ponderosae* Hopkins) in the Kootenai and Lolo National Forests in western Montana, U.S.A. Partial cutting prescriptions consisted of removing from individual stands all trees 17.8, 25.4, and 30.5 cm and larger diameter at breast height (d.b.h.), and prescriptions leaving 18.4, 23.0, and 27.6 m² basal area per hectare. In thinned stands, the first 5 years' results following cutting showed greatly reduced tree losses to mountain pine beetle when compared to untreated stands ($P < 0.01$) on both Forests. No significant differences occurred in tree losses among partial cut treatments ($P > 0.05$). Post-treatment mortality of lodgepole pine 12.7 cm and larger d.b.h. to mountain pine beetle averaged 4.0 to 38.6% on the Kootenai and 6.0 to 17.1% on the Lolo in thinned stands, compared to averages of 93.8 and 73.1% in unthinned stands. Partial cutting appears to be useful for reducing lodgepole losses to mountain pine beetle. In sensitive areas where other resource objectives are important, managers may replace some regeneration harvests with partial cuts to maintain wildlife habitat, increase age class and species diversity, reduce hydrologic and potentially adverse visual impacts.

MOUNTAIN PINE BEETLE (*DENDROCTONUS PONDEROSAE* HOPKINS) INFESTATIONS IN RELATION TO GROWTH AND VIGOR OF LODGEPOLE PINE (*PINUS CONTORTA* DOUGLAS) FOLLOWING THINNING. G.D. AMMAN, USDA, Forest Service, Intermountain Research Station, Ogden, Utah, USA 84401.

Thinning stands of lodgepole pine is thought to increase vigor and thereby reduce susceptibility to mountain pine beetle (MPB) infestation. However, observations in thinned stands show immediate reductions in beetle infestations before significant increases occur in tree growth and vigor.

Four characteristics of infested and uninfested trees were measured: (1) diameter at breast height (dbh); (2) grams of stem wood per square meter of foliage; (3) periodic growth ratio, and (4) leaf area. Only dbh was significantly different between infested and uninfested trees, being larger in the former. Discriminant analysis showed dbh was the most distinguishing characteristic between infested and uninfested trees.

The low amount of MPB infestation in the presence of poor growth and vigor response following thinning suggests factors other than tree vigor regulate beetle behavior in thinned stands. Stand microclimate is suggested as the most significant factor.

MICROCLIMATE AS A FACTOR IN LODGEPOLE PINE (*PINUS CONTORTA* DOUGLAS) STAND AND TREE SELECTION BY MOUNTAIN PINE BEETLES (*DENDROCTONUS PONDEROSAE* HOPKINS). D.L. BARTOS, USDA, Forest Service, Intermountain Research Station, Ogden, Utah, USA 84401.

Thinning lodgepole pine stands results in subtle changes in microclimate. It is believed these changes are a major factor in stand and tree selection by mountain pine beetles during epidemic conditions. Bark and phloem temperature, wind speed, wind direction, and incident solar radiation were measured during the summers of 1986 and 1987 in both thinned and unthinned stands of lodgepole pine. Similar trends and consistent differences were shown between the two stands.

Thinned stands were usually warmer than the unthinned stands, with the largest difference occurring during the hottest part of the day. As expected, temperature was closely correlated with incident solar radiation. Wind speed was higher in the thinned stand; a consistent 1 to 3.5 mph difference was observed.

Thinning of lodgepole pine stands changes the microclimate sufficiently to make the stands less acceptable to mountain pine beetle. Fewer MPB were trapped in a thinned stand (5% of beetles) compared to an unthinned stand (95% of beetles).

UNDERSTANDING SCOLYTID PROBLEMS IN LODGEPOLE PINE FORESTS: THE NEED FOR AN INTEGRATED APPROACH. R.F. Schmitz, USDA, Forest Service, Intermountain Research Station, Ogden, Utah, USA 84401.

The mountain pine beetle (MPB) (*Dendroctonus ponderosae* Hopkins) is the most destructive insect infesting lodgepole pine (*Pinus contorta* Dougl. var. *latifolia* Engelm.). Because little can be done to reverse the trend of an outbreak once under way, prevention of outbreaks is a sensible approach to limit tree killing. Development of preventive strategies is dependent on an understanding of the dynamics of low or "endemic" level populations. Data gathered from single tree infestations has shown the dynamics of endemic MPB populations is closely allied with that of the associated scolytids *Pityophthorus confertus* Swaine and *Ips pini* (Say). The MPB co-inhabits trees infested by these beetles apparently in response to common attractive elements in their respective pheromone bouquets or host volatiles. Infested trees are suppressed saplings or poles well below average in growth, with thin phloem, often partially girdled by porcupines and infected by combinations of *Armillaria* root rot, comandra blister rust (*Cronartium comandrae*) and dwarf mistletoe (*Arceuthobium americanum*). Effective suppression strategies will require integration of knowledge of the dynamics of stand development from sapling through the pole stage and that of the associated scolytids.

THE ROLE OF SEMIOCHEMICALS IN INTEGRATED PEST MANAGEMENT OF THE MOUNTAIN PINE BEETLE (COLEOPTERA:SCOLYTIDAE). John H. Borden*, Centre for Pest Management, Department of Biological Sciences, Simon Fraser University, Burnaby, B.C., Canada V5A 1S6, and B. Staffan Lindgren, Phero Tech Inc., 1140 Clark Drive, Vancouver, B.C., Canada, V5L 3K3.

Semiochemical tree baits have been developed for containment and concentration of mountain pine beetles (MPB) in lodgepole pine stands scheduled for harvesting, for post-logging mop-up, and for containment of small infestations, which can then be easily eliminated by use of systemic pesticide or suitable single tree disposal methods. The aggregation inhibitor verbenone applied on a 10 X 10 m grid reduces attack rates in lodgepole pine stands, even when challenged by tree baits. Verbenone applied next to the bait on a baited lodgepole pine reduces the probability of attack by MPB on the baited tree as well as on nearby trees.

POTENTIAL USE OF SEMIOCHEMICAL FOR INTEGRATED CONTROL OF BARK BEETLES IN EUROPE. A. Bakke, Norwegian Forest Research Institute, Box 61, 1432 Ås-NLH, Norway.

Semiochemicals are essential guidelines for bark beetles in their search for suitable breeding sites. Several species have developed aggregation pheromones while others depend on host tree volatiles. The semiochemicals may be used in integrated pest management for 1. monitoring beetle population; 2. mass trapping and 3. disruption/inhibition beetle infestations. In Europe pheromone dispensers are commercially available for at least 4 species of scolytids. Methods are developed for monitoring Ips typographus. Mass trapping has been used in large scale as part of integrated pest management of I. typographus and Trypodendron lineatum. Experiments in using antiaggregative pheromones to prevent infestation in stored logs have given reduced attack density, but no satisfactory protection.

A NEW POSSIBILITY TO USE BARK BEETLE PHEROMONES?

S. Bomboch, Institut für Forstzoologie, Universität Göttingen, Büsgenweg 3, D-3400 Göttingen, W.Germany.

It is well known that weakened spruce trees cannot be protected from the attack by Ips typographus by the use of pheromone traps. Experiments carried out by Johann have demonstrated that the attractiveness of the pheromone can be enhanced considerably when the plastic trap is replaced by a poisoned spruce log of 1 m length. If one uses as the trap system whole trap trees which are poisoned and baited with pheromone it is not only possible to catch large numbers of I. typographus but one can also drastically reduce the attack of weakened but unpoisoned spruce in the neighbourhood of these trap systems. A report will be given on the experience that has been gained with this method.

PHEROMONE PLUS CUT AND LEAVE FOR SOUTHERN PINE BEETLE SUPPRESSION. T.L. Payne, Department of Entomology, Virginia Tech, Blacksburg, Virginia 24061 USA.

The Dendroctonus frontalis pheromone (-)-verbenone, plus cutting freshly attacked host trees, was used effectively to halt the growth of southern pine beetle infestations in sawtimber size stands. The pheromone was applied in a liquid polymer formulation by a hand sprayer to a small area of bark surface on uninfested trees in a barrier zone in advance of the moving beetle infestation.

REGIONAL VARIATION: A POTENTIAL FACTOR IN THE INTEGRATION OF BEHAVIORAL CHEMICALS INTO SOUTHERN PINE BEETLE MANAGEMENT. C.W. Berisford* and T.L. Payne, Department of Entomology, University of Georgia, Athens, Georgia, USA 30602.

Aggregation and/or antiaggregation pheromones of the southern pine beetle, Dendroctonus frontalis Zimmermann (Coleoptera: Scolytidae) may be used to suppress the growth of infestations. These chemicals have been more effective in some regions than in others. Some of these differences may be due to regional differences in pheromones and/or the response of beetles to pheromones. Bioassays have shown that southern pine beetles collected from Texas, Georgia and Virginia respond preferentially to pheromones produced by beetles collected from their respective geographic regions. Therefore, optimum control of the beetle with behavioral chemicals may require refinements tailored to specific regions.

INTELLIGENT GEOGRAPHIC INFORMATION SYSTEM FOR PREDICTING BARK BEETLE INFESTATIONS. R.N.Coulson, L.A.Graham, and C.L. Lovelady, Department of Entomology, Texas A&M University, College Station, Texas USA 77843.

Herbivory by bark beetles (Coleoptera Scolytidae) produces patches in forest stands that, when taken collectively, influence landscape structure and forest management practices. A geographic information system is used in combination with rule-based reasoning to evaluate the ecological and economic impact of bark beetles at the regional landscape scale.

FORECASTING SOUTHERN PINE BEETLE INFESTATION TRENDS WITH PHEROMONE TRAPS. F.F. Billings, Forest Pest Control Section, Texas Forest Service, Lufkin, Texas, USA 75901.

A method to forecast infestation trends of the southern pine beetle, Dendroctonus frontalis Zimm. (Coleoptera: Scolytidae), has been developed in Texas and pilot tested in selected counties throughout the southern United States during 1986 and 1987. Multiple-funnel traps baited with the synthetic aggregation pheromone "frontalin" and a rapid-release dispenser of turpentine from loblolly pine (Pinus taeda L.) were deployed during the early spring to sample dispersing populations of D. frontalis and its predator Thanosimus dubius F. The relative proportions of bark beetles to predators, as well as mean numbers of bark beetles trapped per day, were data used to predict county- and state-wide infestation trends (increasing, static, or declining) which developed later during the same calendar year. The forecast system shows considerable promise as a simple and reliable means to predict population trends for this destructive forest pest.

TECHNIQUE FOR STUDYING BARK BEETLE DISPERSAL. J.R. Bridges*, W.T. Thoeny, and A.E. Tiarks, USDA, Forest Service, Southern Forest Experiment Station, 2500 Shreveport Hwy., Pineville, LA 71360.

A technique for marking southern pine beetles, *Dendroctonus frontalis*, has been developed using rubidium (Rb) and strontium (Sr) as internal markers. Solutions of Rb and Sr were injected into loblolly pines, *Pinus taeda*, (25 cm dbh) at rates of 5, 10, 20, 30, and 50 g of RbCl and SrCl₂ in 150 ml of water. Ten shallow pit injectors spaced evenly around the tree delivered solutions to the outer 4-5 growth rings at pressures of 30 psi. Southern pine beetle attacks were initiated on the trees using pheromone 5 weeks after injection. Trees were felled when brood beetles reached the pupal stage, and infested bolts were placed in rearing cans to collect the emerging beetles.

Loblolly pines were successfully labelled with high concentrations of Rb and Sr, which remained elevated for 15 weeks. Beetles developing in labelled trees were also labelled. At the highest concentration of Rb, the marker was easily detected in individual beetles. Therefore, the technique is a suitable mark-recapture method to study the movement of individual bark beetles.

HOST LOCATION: AN IMPORTANT CONSIDERATION IN THE USE OF EXOTIC NATURAL ENEMIES FOR THE BIOCONTROL OF NATIVE SCOLYTIDS. N.J. Mills, CIBC, Imperial College, Silwood Park, Ascot, Berks SL5 7PY, England.

Biological control has classically been directed towards the control of introduced pests, while the considerable potential for the use of exotic natural enemies in the control of native pests has largely been neglected. In addition to the usual criteria for the selection of biocontrol agents this latter approach requires an assessment of the compatibility of exotic candidates with the target host in terms of their ability to locate the novel host, its acceptance for oviposition and its suitability for subsequent development. In the case of cryptic hosts, such as scolytids, host location is the dominant factor influencing the compatibility of new host-natural enemy associations. The roles of heat, sound and volatiles in the host location mechanism of scolytid parasitoids are discussed as a preliminary to the selection of suitable candidates for use in biological control.

THE RELATION OF BAST SCALE AND BARK BEETLE OUTBREAKS TO MANAGEMENT OF PINE PLANTATIONS IN ISRAEL. Z. MENDEL, DEPT. ENTOMOLOGY, ARO, BET DAGAN, 50250, ISRAEL.

A hypothesis is presented to explain the high frequency of bark beetle outbreaks in the Judean Hills in Israel. *Orthotomicus erosus* and *Pityogenes calcaratus* are among major insects affecting the life cycle of natural uneven-aged pine stands. These scolytids attack following silvicultural thinning in plots of even-aged plantations injured by the pine bast scale *Matsucoccus josephi*. It is suggested that bark beetle outbreaks are the outcome of temporary weakening of the trees due to extreme opening of the stand, coinciding with high flight aggregation of these beetles. The large flights resulted from mass breeding in large tree slash and windthrows following extensive thinning in adjacent older plantations decline due to *M. josephi*. Ecological pest management of pine plantations in Israel should focus on early thinning, integrated with bast scale management, to prevent excessive stand opening at a later stage due to injury by *M. josephi*.

THE SOUTHERN PINE BEETLE AND THE RED-COCKADED WOODPECKER: POTENTIAL FOR INTERACTION. D. L. Kulhavy*, J. H. Mitchell, School of Forestry, Stephen F. Austin State University, Nacogdoches, Texas, USA 75962, R. N. Conner, Wildlife Habitat and Silviculture Laboratory, Southern Forest Experiment Station, Nacogdoches, Texas, USA 75962.

Red-cockaded woodpecker colonies and surrounding 50 ha foraging areas were hazard and risk rated for susceptibility to the southern pine beetle (SPB) *Dendroctonus frontalis*, on the Angelina National Forest in eastern Texas. In 1982, 42 percent of the stands were classified moderate to extreme hazard. In 1986, due to SPB control activities and silvicultural operations, the hazard was 33 percent. Colony tree resistance was measured by resin flow, crystallization rate and xylem moisture potential. Resin flow measured at two, eight and 24 hours was higher for inactive colony trees than for active and potential cavity trees. Crystallization rate and xylem moisture potential did not differ between active, inactive and potential cavity trees but differed seasonally.

MASS OUTBREAKS OF IPS BARK BEETLES IN BHUTAN AND THE REVISION OF THE GENUS IPS FOR THE HIMALAYAN REGION. H. Schmutzenhofer, Federal Forestry Research Institute, A-1131 Vienna - Schönbrenn, Austria.

An extended bark beetle epidemic caused by the new species *Ips schmutzenhoferi* Holzschuh was identified in West-Bhutan. More than 3000 ha in the mixed conifer belt, altitude between 2700 and 3250 m, have been attacked, causing a loss of 2 mill. cbm gross volume. Spruce, *Picea spinulosa*, blue pine, *Pinus wallichiana* and when felled, larch, *Larix griffithiana*, are hosts. Local fir, hemlock and juniper are not suitable for *Ips*-breeding. Artificial breeding of this *Ips* on Norway spruce and Scots pine is possible. A pest management plan based on integrated control methods was approved. A specific pheromone was developed and successfully tested. A large scale mass outbreak of *I. longifolia* attacking chir pine, *P. roxburghii* in the lower subtropical conifer belt was also observed. Main reasons for all epidemics were drought, lack of forest hygiene measures, in the chir pine wind fellings and previous defoliation. The genus *Ips* was revised for the Himalaya region and grouped into three species: *I. longifolia* Stebb. distributed in altitudes between 500 and 2000 m all over the Himalayas on chir pine. *I. schmutzenhoferi* occurring in the east Himalaya and *I. stebbingi* Strohm. (syn. *I. rippentropi* Stebb. and *I. blandifordi* Stebb.) in high altitudes in the west Himalaya attacking chilgoza pine *P. Gerardiana*, blue pine, spruce and probably other conifers.

ON THE DEVELOPMENT OF IPM IN GERMANY.

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With the exception of *Dendrolimus pini* it was not possible to control mass propagation of forest pests effectively until the end of the twenties of this century. Before this time it was therefore necessary to find ways and means for preventive pest management. These efforts, which integrated all known methods at any given time, trace back to the middle of the 18th century. During the course of the decades, methods were worked out which are still in full use today and which are known in the German-speaking areas as Waldhygiene. In detail these methods concern the establishment, care, and harvest of forests. Later on the use of insecticides, and today to a growing extent biotechnical procedures were integrated. It is pointed out that the application of the latter can also create the danger of unwanted ecological side effects.

DEVELOPMENT OF INTEGRATED PEST MANAGEMENT SYSTEMS FOR FOREST DEFOLIATORS IN NORTH AMERICA. F. William Ravlin, Department of Entomology, Virginia Tech University, Blacksburg, Virginia 24061.

Because of the unique ecological, spatial, temporal, social, and political features of forest systems, significant technological and philosophical advances have been made in the development of integrated pest management (IPM) systems for forest defoliators. Technological advances include large-area monitoring systems, automated data acquisition systems, computer-aided decision-support systems, and novel chemical and nonchemical control tactics. In addition, the overall philosophical foundation of IPM has been richly supplied with science and thought through forest IPM research. However, implementation of forest IPM has not been without its problems. Pests such as the gypsy moth have demonstrated that social and political constraints may well be more of a stumbling block to continued development than our understanding of ecology and population dynamics, and our ability to produce decision-support tools.

The objective of this paper is to describe the development of IPM technology for forest defoliators in North America and some of the major constraints to implementation of resulting systems.

INTEGRATED CONTROL OF SCOTS PINE DEFOLIATORS IN FINLAND (*NEODIPRION SERTIFER*, *Bupalus piniarius*). Erkki Annala, Finnish Forest Research Institute, Pl 18, 01301 Vantaa, Finland.

In Finland the European pine sawfly (*Neodiprion sertifer*) has mass outbreaks at ten-year intervals, on the average. A nuclear polyhedrosis virus has been used for control since 1972. When the days are mostly warm and sunny during the two-week period after application the mortality of the larvae is practically 100%. When a pine stand is defoliated in two successive years the growth is reduced by about 30% during the ten-year period after the attack. Fertilizing the stand with nitrogen at a rate of 150 kg N/ha can increase the increment of the trees to the same level as that of healthy trees. The latest mass occurrence of the pine looper moth (*Bupalus piniarius*) was in eastern Finland, affecting about 1500 ha in 1983-84. Diflubenzuron was used in 300 ha of forest in the summer of 1984, resulting in the collapse of the population. In spite of the treatment about 30% of the trees were killed in the area most heavily defoliated by the larvae.

DEVELOPMENT OF AN INTEGRATED APPROACH TO CONTROL OF PINE BEAUTY MOTH IN SCOTLAND. H.F. Evans*, J.T. Stoakley, A.D. Watt, S.R. Leather, Forestry Commission, Alice Holt Lodge, Wrecclesham, Farnham, Surrey, GU10 4LH, England.

Pine beauty moth (PBM), *Panolis flammea* (D & S), is native to Britain where it is endemic on Scots pine. During the 1970s destructive populations of PBM were seen for the first time on lodgepole pine plantations in Scotland. Early use of *Bacillus thuringiensis* failed to prevent tree mortality. This led to the development of an integrated research programme designed to combine effective monitoring and control with a more fundamental approach to understanding why this insect had become epidemic. Detailed studies on use of chemical insecticides have resulted in the successful development of ultra low volume controlled droplet application of both fenitrothion and diflubenzuron. Collaboration with the NERC Institute of Virology at Oxford is providing promising results on the potential use of a baculovirus for PBM control. Studies on basic biology and population dynamics have linked outbreaks to poorly drained peat soils as well as to certain seed origins of lodgepole pine. These data are being incorporated into proposals for the effective management of this insect in the future.

THE WINTER MOTH IN EASTERN NORTH AMERICA. Douglas G. Embree, Maritimes Forestry Centre, Canadian Forestry Service, P.O. Box 4000, Fredericton, New Brunswick E3B 5P7.

Over 25 years ago the winter moth, an introduced European pest of hardwoods in Nova Scotia, was brought under control by the introduction of two parasites. The present status of the winter moth and occurrences in orchards and occasional flare-ups in forests and urban areas in the Province over the past quarter of a century are reviewed. The 1952-1962 studies in Nova Scotia are reexamined in the light of subsequent studies in the United Kingdom and British Columbia. The economic impact of the control of the winter moth on the forestry sector of Nova Scotia is addressed from the aspect of integrated pest management.

PEST CONTROL IN NATURAL AND MAN-MADE FORESTS IN NORTHERN JAPAN. Y. Higashiura, Hokkaido Forest Experiment Station, Shintoku, Tokachi, Hokkaido 081, Japan.

Natural enemies and life history traits were studied for control of *Choristoneura jezoensis* Yasuda et Suzuki, *Dendrolimus superans* (Butler) and *Lymantria dispar* L. in Hokkaido, northern Japan.

Outbreaks of the todo-fir budworm, *C. jezoensis*, occurred during 1965-75 in plantations of *Abies sachalinensis*. The population in natural forests, however, remained low density levels during the period. The difference is ascribed to the different numerical response of a parasite, *Lissonota saturator* (Thunberg). Natural mixed forests are preferred to man-made forests for controlling pests. In IPM of forest pests, however, it is difficult to adopt cultural methods such as agronomic practices.

I present control methods utilizing life history traits of the pests. The hemlock caterpillar, *D. superans*, overwinters in the soil in larval stage. For control of the pest, we fastened every tree trunk with a vinyl tape to impede larvae crawling up. Another method is for the gypsy moth, *L. dispar*. In Hokkaido the female oviposits below the branch. Higher egg masses suffered higher predation by birds. The predation increased by pruning lower branches.

IPM for *Eucalyptus* nursery insects in Brazil. J.C. Zanuncio*, N. dos Anjos, G.P. Santos and E.F. Vilela, Depto. de Biologia Animal, Universidade Federal de Viçosa. 36570 Viçosa, MG, Brazil.

Insect pests of *Eucalyptus* nursery in Brazil include cutworms, crickets and termites. In the past, chemical control was the only method used extensively by Brazilian Forest Companies to control these insects, causing environmental problems like water pollution. Techniques including mechanical control, different methods to produce seedlings, adequate treatment of personal, temporary nursery were shown to be important measures for IPM for these insects in Brasil.

INTEGRATED PEST MANAGEMENT OF SEVERAL FOREST DEFOLIATIONS IN TAIWAN. Y. C. Chang, Taiwan Forestry Research Institute, Taipei, Taiwan, R. O. C. 10728

The main defoliators in plantation forests of Taiwan are the casaurina tussock moth (*Lymantria xyliana*), the pine caterpillar (*Dendrolimus punctatus*), the leucaena psyllid (*Heteropsylla cubana*), the coconut leaf beetle (*Brontispa longissima*), Formosan alder leaf beetle (*Linaeidea formosana*) and the bamboo mirid (*Mecistoscelsia scirteloides*). Some of the achievement in operations of integrated pest management of these insects are promising, and are summarized below:

1. The casaurina tussock moth has been effectively controlled by aerial spray of insecticide and a microbial agent, *Beauveria bassiana*.
2. The pine caterpillar can be killed by spraying a mixture of 3 microorganisms.
3. The coconut leaf beetle and the bamboo mirid can be controlled by the use of parasites in cooperation with insecticides.
4. The Formosan alder leaf beetle damage can be avoided by mixture planting with other tree species or resistant varieties.

TOWARDS INTEGRATED CONTROL OF CEPHALCIA ABIETIS L. AS A DEFOLIATOR OF THE NORWAY SPRUCE IN CENTRAL EUROPE. E. Führer* and P. Fischer, Institut für Forstentomologie und Forstschutz, Universität für Bodenkultur Wien, Gregor-Mendel-Strasse 33, A-1180 Vienna Austria.

Cephalcia abietis L. (Hymenoptera: Pamphiliidae) causes severe damage to middle aged and old stands of the Central European uplands at altitudes between 500 and 1000 m. Its epidemics usually are starting from poor and degraded forest sites. The wasp generally has a two or three years' generation cycle.

Chemical control is more or less inefficient because of the life habits of the larvae. Thus, attempts are running to find alternative methods of outbreak prevention or control. The biological and ecological character of this insect pest gives different approaches to an integrated control program.

In view of the site conditions specific to outbreak areas, it seems promising to increase tree resistance by fertilization of the forest stands. The two to three years' stay of the eonymphs in the soil provides a good opportunity to predators and parasites of reducing the pest population. It has proved quite serviceable to fence the infested site for keeping there a pack of wild boars. Eonymph mortality up to 70 % within a year was caused by breaking up the soil. Entomophilic nematodes (*Steinernema*) are important parasites, invading and killing eonymphs. Acidification of forest soils seems to check nematode activity. Fertilization may improve its micro-environment and increase the parasitic effect on the eonymphs. Artificial inoculation of laboratory-reared nematodes is also considered as a promising method. Full-grown larvae of *Cephalcia* are sensitive to *Beauveria bassiana*; its application to soil surface induces infections of nymphs immigrating to ground.

THE PINE CATERPILLAR DENDROLIMUS PUNCTATUS IN VIET NAM AND THE POTENTIAL FOR INTEGRATED PEST MANAGEMENT. R.F. Billings, Forest Pest Control Section, Texas Forest Service, Lufkin, Texas, USA 75901.

Frequent outbreaks of the native pine caterpillar, *Dendrolimus punctatus* Walker (Lepidoptera: Lasiocampidae) are beginning to plague young plantations of *Pinus massoniana* and *P. merkusii* in Viet Nam. Severe defoliation reduces volume growth and resin production; repeated defoliation may cause tree mortality. Current control programs rely heavily on manual methods (hand removal and destruction of life stages), use of light traps to catch adult moths, and some insecticide applications. A more integrated approach to prevention and control has been suggested in pine forestry programs to reduce defoliator problems. Short-term approaches should focus on biological control, including production and application of microbial agents, parasites and predators, rather than total reliance on chemical pesticides. Long-term solutions will need to involve improved forest management practices, including the establishment of mixed stands of different pine species or pines and hardwoods, replacement of pines with non-host tree species on high hazard sites, increased fire prevention, and further professional training of Vietnamese protection personnel.

INTEGRATED PEST MANAGEMENT AND THE EASTERN SPRUCE BUDWORM. J. Hudak, Newfoundland Forestry Centre, Canadian Forestry Service, Box 6028, St. John's, Newfoundland, Canada A1C 5X8.

The eastern spruce budworm, *Choristoneura fumiferana* (Clem.), is one of the most widely distributed and the most destructive forest insect in North America. The recent outbreak of this pest extending over the 1970s and early 1980s was unprecedented in size and severity. Unparalleled research efforts during the outbreak in most political jurisdictions made major contributions to the components of the classical integrated pest management system including population dynamics and epidemiology of the budworm. The dynamics of forest stands in relation to budworm populations, the socio-economic impact of the budworm on resource values, the treatment strategies and cost benefit analysis and the basic mechanism of pest management decision making in the overall framework of forest management.

The vast geography of the budworm inherently includes forest stands of different species content, with variable site and climatic conditions which result in significant differences in budworm host interactions. Such differences induce additional variability in the response and role of secondary pests in the overall impact of the budworm. Furthermore, major differences exist in the basic resource management policy of the political jurisdictions. The sum of the preceding factors preclude a generally functional and widely accepted integrated management system for the eastern spruce budworm, but sufficient information exist for developing it for some regions.

APPALACHIAN GYPSY MOTH INTEGRATED PEST MANAGEMENT DEMONSTRATION PROJECT. R.C. Reardon, Forest Pest Management, U.S. Forest Service, Morgantown, WV 26505.

The USDA Forest Service was directed by Congress through the 1987 Supplemental Appropriation to initiate an IPM special project, Appalachian Gypsy Moth IPM (AIPM) Demonstration Project, to minimize the spread and adverse effects of the gypsy moth. The overall 5-year objectives of the Project are: (1) to minimize the spread and adverse effects of gypsy moth within the Project area, (2) to develop a general prototype IPM structure that can be implemented anywhere in the U.S., and (3) to evaluate a containment system for managing gypsy moth populations. The Project area, located in West Virginia and Virginia, encompasses 20 and 18 counties, respectively. In 1988, survey and monitoring will be conducted on 13.5 million acres.

THE GYPSY MOTH: HOW INTEGRATED IS PEST

MANAGEMENT? E. Alan Cameron, Department of Entomology, Penn State University, University Park, PA, USA

The gypsy moth, *Lymantria dispar* L. (Lepidoptera: Lymantriidae), an introduced major pest of hardwood forests in the northeastern United States and more recently in eastern Canada, has been and continues to be a target for control programs ranging from eradication to benign neglect. Increasing emphasis has been put on "integrated pest management," at least administratively, in the last several decades. This has encouraged wide-ranging research efforts, both basic and applied; substantial public monies have been made available to support these studies.

Various components of pest management programs, including parasites, predators, pathogens, the pheromone, sterile males, chemical and biological insecticides, and site relationships are described and evaluated. The success of pilot programs conducted in infested areas is assessed. Finally, the likelihood of successful management of the gypsy moth, using various assumptions related to geographical location, economic constraints, and aesthetic and production goals, is evaluated.

INTEGRATED PEST MANAGEMENT OF THE DOUGLAS-FIR TUSSOCK MOTH. R.R. Mason* and B.E. Wickman, USDA Forest Service, Pacific Northwest Research Station, La Grande, Oregon.

The Douglas-fir tussock moth is one of the most injurious forest defoliators in western North America. Densities of most tussock moth populations fluctuate with considerable regularity. Fluctuations on warm-dry sites where populations have a high intrinsic rate of increase are more likely to reach outbreak numbers periodically than where rates of increase are less. Such cycles of abundance are fundamental to the tussock moth system and are not likely to be changed in susceptible host types. Modern pest management programs emphasize annual monitoring of populations in forests with outbreak histories to determine patterns of numerical behavior and to predict early trend. When outbreaks develop several environmentally safe chemical and microbial insecticides effectively reduce larval numbers and prevent serious defoliation. Computer models that predict growth loss, tree mortality, and top-kill during outbreaks are available to aid decision making. Silvicultural practices that favor seral non-host species on high risk sites may be the best prescription for reducing the impact of tussock moth outbreaks.

INTEGRATED PEST MANAGEMENT OF FOREST DEFOLIATORS IN THE SOUTHEASTERN UNITED STATES. R. A. Goyer, Department of Entomology, Louisiana State University, Baton Rouge, Louisiana, USA 70803

A multitude of defoliating insect species occur in the temperate and sub-tropical forests of the southeastern U.S. Two groups, however, stand out as persistent, annual problems that demand the attention of forest pest managers. These are the tent caterpillars (Lepidoptera: Lasiocampidae) and the pine sawflies (Hymenoptera: Diprionidae). Pest management tactics developed to date have involved population dynamics and modeling as well as biological and cultural controls. Pheromone trapping schemes to provide an indication of relative population density have been developed for several important defoliator species. The use of traditional chemical controls has been inhibited by the diverse forest fauna, economics, and environmental sensitivity.

New pest problems appear to be emerging as a major focus of research efforts. This has been a result of shifts in resource usage as well as tree stress and subsequent predisposition to previously unimportant pest species.

INTEGRATION OF EARLY VIRUS TREATMENT WITH A PHEROMONE DETECTION SYSTEM TO CONTROL DOUGLAS-FIR TUSSOCK MOTH POPULATIONS AT PREOUTBREAK LEVELS. I.S. Otvos, and R.F. Shepherd, Canadian Forestry Service, Pacific Forestry Centre, 506 West Burnside Road, Victoria, British Columbia, Canada V8Z 1M5.

A naturally occurring virus of high virulence often leads to the development of an epizootic late in the outbreak cycle but not before significant damage to the trees occurs. This virus can be mass produced in the laboratory, and when applied in the field causes epizootics. If the virus can be applied early in the outbreak cycle severe defoliation can be prevented. This, however, requires an early warning system. This paper discusses the development of a pheromone monitoring system and its integration with a virus treatment. Procedures are described for the determination of stands susceptible to Douglas-fir tussock moth by overlaying maps of past outbreaks over maps of forest and habitat types, and climatic zones. Pheromone traps are placed and monitored annually in the susceptible stands. Measuring annual trends of moth density will indicate time and location of the next outbreak. This is confirmed by ground reconnaissance. Insect density and defoliation is predicted from egg-mass and larval sampling. The virus can then be applied from the air or from the ground, into threatened stands to initiate an epizootic. This prevents the development of an outbreak and minimizes tree damage. The virus appears to spread and field tests with reduced dosages indicated that a small amount of virus applied can decimate larval populations and prevent tree mortality at considerably reduced cost.

THE EFFECTS OF THINNING AND FERTILIZATION ON WESTERN SPRUCE BUDWORM, *CHORISTONEURA OCCIDENTALIS* FREEMAN (LEPIDOPTERA: TORTRICIDAE), AND GRAND FIR GROWTH.

B.E. Wickman*, R.R. Mason, USDA Forest Service, Pacific Northwest Research Station, La Grande, Oregon and Thomas J. Savage, formerly with Oregon State University, Corvallis, Oregon.

A cooperative silviculture study with Oregon State University and the Forest Service was undertaken in 1984. Analysis of foliar N in 1986 showed that thinning did not significantly alter any of the foliage chemical fractions measured, but fertilization at 350 kg per hectare increased N and free amino acids. Measurements in 1987 included foliar terpenes and showed that fertilization reduced ($P < 0.05$) the concentration of Beta-pinene. Fertilized trees produced significantly ($P < 0.05$) heavier spruce budworm female pupae than did the controls. Insect herbivore biomass was also higher ($P < 0.05$) on both thinned and fertilized plots than on control plots. Percent defoliation, however, was significantly ($P < 0.005$) lower in the fertilized plots. There was also significantly ($P < 0.01$) more new shoot biomass produced on fertilized trees than on controls. Fertilized trees apparently did not respond by increasing defensive chemicals in 1986 and 1987, but did produce more foliage than could be consumed by the budworm and other herbivore larvae.

INSEX: AN EXPERT SYSTEM FOR USE OF CHEMICALS AND MICROBIALS FOR FOREST DEFOLIATORS. J.L. Robertson, Pacific Southwest Forest and Range Experiment Station, USDA, Berkeley, California, USA.

INSEX, an expert system for management of North American defoliators, will be described. Four environmental situations (backyard, park/recreational area, forest, and wilderness area) are considered. Recommendations are based on the presence of key environmental factors and organisms such as water bodies, bees, edible plants, and endangered species. More than 75 insect species and 150 tree species in the United States and Canada are included. Chemical pesticides, microbials, physical control, or biological control are recommended depending on the user's specific problem.

USE OF PHEROMONES FOR FOREST DEFOLIATORS OF NORTH AMERICA, WITH EMPHASIS ON CANADA. G.G. Grant, Forest Pest Management Institute, Canadian Forestry Service, Sault Ste. Marie, Ontario, Canada P6A 5M7.

A major objective of pheromone monitoring research is to replace costly and time-consuming larval and egg sampling methods to estimate the size of insect populations in the current year and predict damage or population levels for the subsequent year. The extent to which progress has been made toward operational pheromone monitoring systems that can achieve this goal will be reviewed along with the practical problems associated with choice of trap type, trap repellency, and selection of lure dosage. Monitoring for simple detection, determination of geographical distribution, or phenological relationships will be included. Examples will cover major pests of deciduous and coniferous trees.

POSSIBILITIES AND THEIR LIMITS FOR INTEGRATED PEST MANAGEMENT IN GERMAN FORESTS. J. Schoenherr, Forestzoological Institute, University of Freiburg, D-7801 Freiburg, Germany.

Aviochemical control measures against forest insects become more difficult each year in Germany because of an increasing resistance movement of the inhabitants of neighboring areas. Although under certain circumstances integrated pest management is used in German forests since long time, it has been forced during the last years. At the moment certainly a total renunciation of pesticides is not possible, but their use has been reduced to low rates of less harmful chemicals and aviochemical control measures are restricted to events of risk of a total loss of the forests. The lecture shows different examples of integrated pest management in German forests and their limits for practical applicability.

PROSPECTS FOR GENETIC CONTROL OF THE GYPSY MOTH. C.P. Schwalbe, V.C. Mastro and R.W. Hansen, Otis Methods Development Center, Animal and Plant Health Inspection Service, USDA, Otis Air National Guard Base, Massachusetts 02542, USA.

Male gypsy moths that have been irradiated as pupae with a substerilizing dose of 10 Krads gamma radiation and mated with normal females yield F₁ progeny that are sterile. This inherited sterility enhances classical sterile insect release methods since control is exerted on the target population for two generations with release only in the first generation. However, the logistical difficulties associated with large-scale deployment of partially sterile males renders genetic control impractical on a large scale. Diapausing F₁ eggs (progeny of 10 Krad male x normal female) can be stockpiled in the laboratory and released into target populations, thus greatly simplifying release operations. F₁ eggs hatch and larvae develop on foliage in synchrony with wild insects. The overflooding ratio of F₁ sterile: fertile males will reduce reproduction in the year of release, provided that development and survival are comparable to wild populations. Releasing F₁ egg masses marks a significant step forward in making sterile insect technology operational for the gypsy moth. Field trials in isolated infestations have been conducted and the technique has been successful in eradicating an isolated population in Bellingham, Washington, USA. Prospects for its continued use in gypsy moth management programs are discussed.

GENETIC MANIPULATION IN THE CONTROL OF LYMANTRIA DISPAR (L.). Professor Sir Cyril (A.) Clarke, Department of Genetics, University of Liverpool, L69 3BX PO 147, England.

Using the heterozygotic test on embryos, larvae and pupae of L. dispar, we have shown that the great excess of males described by Goldschmidt in certain race crosses is not due to sex reversal but to the Haldane effect, and that the males in these crosses are fully fertile. Therefore gene manipulation on the Goldschmidt theory would not be successful in pest control. Encouragement of inbreeding in small colonies might be effective but is probably easier said than done. Genetic engineering of the foodplant could be tried, but might be risky to other species, including Man.

Although there are marked racial differences in L. dispar we have not encountered any phenotypic polymorphism, although this apparently occurs with the esterases.

In the genus Oreigia the Japanese female O. thyellina assembles O. antiqua but the latter will not attract O. recens, with which it is sympatric. The relevance of this finding will be discussed.

DROUGHT STRESS AND OUTBREAKS OF THE SPRUCE BUDWORM: IMPLICATIONS FOR INTEGRATED PEST MANAGEMENT. William J. Mattson* and Robert A. Haack, USDA, North Central Forest Experiment Station, 1407 South Harrison Road, East Lansing, Michigan 48823, USA.

Drought stress of the principal host trees, balsam fir (Abies balsamea) and white spruce (Picea glauca), may lead to outbreaks of the spruce budworm (Choristoneura fumiferana) – for different reasons. Drought stress increases host nutritional suitability (increased N and soluble sugars) of white spruce more than that of balsam fir. Hence, budworm are more fecund on stressed spruce. We propose that drought stress brings about a confluence of more nearly optimal biochemical, physiological, and environmental conditions for the budworm, and that these changes act synergistically in the growth of their populations. In such conditions, both natural enemies and biocides/pesticides could be rendered less effective in controlling budworm populations. Attention needs to be given to defining the thermal regimes for optimal efficacy of the natural enemies and biocides/pesticides.

OUTBREAKS OF THE PINE BEAUTY MOTH ON LODGEPOLE PINE: THE INFLUENCE OF HOST PLANT SPECIES AND SITE FACTORS. A.D. Watt*, G.R. Leather, H.F. Evans; Institute of Terrestrial Ecology, Bush Estate, Penicuik, Midlothian EH26 0QB, Scotland

Outbreaks of the pine beauty moth, Panolis flammea, in Scotland are restricted to lodgepole pine, and do not occur on the native host, Scots pine. Lodgepole pine plantations growing on deep unflushed peat are particularly prone to attack. Several avenues of research have been followed to try to establish whether the observed outbreak behaviour of P. flammea is the result of temporal, spatial and genetic variability in host-plant susceptibility, including: monitoring natural and artificially manipulated populations; studies of adult and larval behaviour; experimental manipulation of moisture and nutritive status; and analyses of foliar chemistry. The role of parasites and predators in the abundance of P. flammea is also being considered through various experimental techniques and surveys of natural enemy abundance. The value of some of the results for the management of this pest is being assessed in a population simulation model.

HOST QUALITY EFFECTS ON PINE SAWFLY PERFORMANCE.

Stig Larsson, Dept. of Plant and Forest Protection, Swedish Univ. Agric. Sci., S-750 07 Uppsala, Sweden.

Food quality has been suggested as an important factor when explaining distribution and population fluctuations in needle-eating insects. It has been proposed that environmental influences, such as drought, air pollution, or fertilization, can cause changes in needle characteristics with consequent effects on insect performance. Whether environmentally induced effects on food quality significantly affect insect population numbers depends on how sensitive the insects are to variation in needle characteristics. I shall describe how sawfly larvae (*Neodiprion sertifer*) respond to variation in needle quality, i.e. concentrations of resin acids, simple phenolic compounds, and nitrogen. The bearing of these experiments on current theories of tree-insect interactions will be discussed.

INFLUENCE OF PONDEROSA PINE WATER STRESS ON PINE SAWFLIES - TEST OF THE NUTRIENT PARTITIONING HYPOTHESIS. M. R. Wagner, School of Forestry, Box 4098, Northern Arizona University, Flagstaff, AZ 86011 USA.

Field experiments to determine the effect of induced water stress in ponderosa pine, *Pinus ponderosa*, on a free-feeding sawfly, *Neodiprion fulvipes*, (Hymenoptera: Diprionidae) have been conducted since 1983. Supplemental watering and trenching of pole-sized ponderosa pines was successful in creating populations of high and low water stressed trees. These treatments had significant but variable effects on sawfly performance parameters. Several hypotheses to explain the effect of water stress on insect herbivores are being concurrently evaluated. Total nitrogen in ponderosa pine foliage ranged from 1.1 to 1.4 percent and was not significantly affected by the stress treatment. Changes in foliage nitrogen as a result of stress is not related to changes in insect performance.

FOLIAR NUTRIENTS AND THE SPRUCE BUDWORM. Karen M. Clancy, Rocky Mountain Forest and Range Experiment Station, 700 S. Knoles Drive, Flagstaff, AZ 86001 USA

Current theory on how foliar nutrients affect populations of forest defoliators has emphasized the singular importance of nitrogen and water as critically limiting nutrients for insect herbivores. Outbreak populations of spruce budworms have been attributed to elevated concentrations of soluble nitrogen in plant foliage resulting from drought stress.

I have been conducting experiments to evaluate the role of host plant nutritional factors as potential resistance mechanisms to western spruce budworm (*Choristoneura occidentalis*) attack. I have quantified the budworm's response to different levels of nitrogen, water, and sucrose in artificial diets. The experimental results do not support the hypothesis that the budworm is limited by the normal concentrations of nitrogen or water found in host plant tissue. Sugars may be limiting when nitrogen is low. Results to date suggest that nitrogen is not the only nutrient influencing budworm performance, and that other nutrients, such as minerals or sugars, may be equally or more important than nitrogen. The past emphasis on the singular role of nitrogen as the most important host plant nutrient driving population fluctuations of forest defoliators needs to be re-evaluated.

IPM AND EASTERN SPRUCE BUDWORM: LESSONS LEARNED IN MAINE 1950-85. Lloyd C. Irland, The Irland Group* and John B. Dimond, University of Maine.

The eastern spruce budworm outbreak in Maine caused millions of cords of mortality and growth loss from 1950 to 1985. It prompted extensive and costly spray programs and generated considerable litigation and public controversy. Extensive experience in survey and detection, spray materials and application technology, silvicultural approaches, and policy was gained. We have recently completed a detailed retrospective on this experience for the Maine Forest Service.

The ability to mount an effective IPM response to the spruce budworm in Maine in this period was constrained by overoptimistic faith in the ability of pesticides to solve the problem, as well as by inadequate access to remoter areas of the woods and poor wood markets until well into the mid 1970's. In addition, standard IPM prescriptions, as for silvicultural hazard reduction treatments, were poorly validated and often difficult to implement or not cost-effective. A major hazard to effective response to the next outbreak is the tendency to place budworm on the "back burner".

NUTRITIVE QUALITY AS A DEFENSE AGAINST HERBIVORES. E. Haukioja, Laboratory of Ecological Zoology, Department of Biology, University of Turku, SF-20500 Turku 50, Finland.

The effects of the nutritive quality of plant on insects depends on the balance among positive and negative foliar factors for the feeding insect. Low plant quality may protect the plant from herbivorous insects but insects may also compensate for the poor quality food by eating for a longer time in which case the plant may lose more biomass. Whether an insect really prolongs the feeding period on poor diets depends on mortality risks and on benefits achieved when consuming more. From the plant's point of view the low nutritive quality may be an active defense or an incidental by-product. A defensive function, in a strict sense, of the low nutritive quality can be best demonstrated in cases where plants respond to the threat of feeders by decreasing foliage quality. Foliage damage induced lower foliage quality in four Finnish tree species of which two regularly experience large insect outbreaks. Just in these two species did insect feeding activate a stronger response than manual damage of foliage.

MEASURING DEFOLIATOR INSECT DAMAGE. R.I. Alfaro, Canadian Forestry Service, Pacific Forestry Centre, Victoria, B.C. Canada, V8Z 1M5.

The damage caused by defoliating insects to the forest resources is reviewed and measurement techniques are discussed.

SOCIAL, ECONOMIC AND POLICY ASPECTS OF INTEGRATED PEST MANAGEMENT OF FOREST DEFOLIATORS IN INDIA. K.S.S. Nair, Division of Entomology, Kerala Forest Research Institute, Peechi, Kerala, India 680 653

About half a dozen insects are recognised as important forest defoliators in India, but except for some early attempts for silvicultural cum biological control of teak defoliators (not yet operational), no progress has been made towards integrated pest management (IPM). The main constraints are socioeconomic - the low priority accorded to forest pest control compared to agricultural pest control due to more pressing demand for increased food production, the 'generation gap' between traditionally trained forest entomologists and the ideal IPM researcher, and the inflexibility of institutional structures to meet the new demands of IPM research, evaluation and implementation. Virtually all forest in India is Government (Govt) owned, and all operations are carried out by Govt agencies, a situation conducive for implementation of IPM. But unlike in agriculture where the Govt is actively encouraging a shift from chemicals to IPM, forest pest control is largely a neglected field, although in the past this neglect has saved the forest ecosystem from the onslaught of chemical pesticides. With more data on the economics of damage, Govt policy can now be expected to direct the forest pest control effort to the path of IPM.

IPM AND GOVERNMENT POLICY - FACT AND FANCY. K.H. Knauer (USA)

No Abstract

FOREST PEST MANAGEMENT SOCIOPOLITICS. D.L. Dahlsten* and S.H. Dreistadt, Division of Biological Control, University of California, Berkeley, California 94720, U.S.A.

Successful forest pest managers must integrate complex technical considerations with important social and political concerns. Interdisciplinary decision-making is mandated in the United States by legislation including the National Environmental Policy Act and the National Forest Management Act. Environmentalists have effectively used this legislation as the basis for lawsuits to modify or halt forest management programs focused on direct insect control through the aerial application of broad-spectrum insecticides. Case studies on the control of defoliating insects demonstrate that forest pest management decisions are not the purview just of technically trained foresters seeking increased timber yields. The demands for multiple use and improved environmental quality cannot be ignored. The trend toward greater public, legislative, and judicial involvement in forest pest management decision-making will undoubtedly continue. Successful managers must be responsive to these social and political concerns.

CHALLENGES FOR THE FUTURE. G.N. Mason. United States Department of Agriculture, Forest Service, Washington, DC.

The forests of the world cover approximately 7.5 billion acres--almost 23 percent of the total land area of the Earth, and amounting to roughly 2 acres per capita. persons by the year 2000--with associated demands for food and fiber, impacts on the land and its productivity, and effects on the environment--will present an exciting, difficult, and continuing challenge to resource managers.

Research, academic, and resource management professionals face the particularly difficult challenge of analyzing and anticipating longterm research, technology, and educational needs in order to design effective programs for training professionals and to develop and implement technology capable of meeting these changing resource- and pest-management demands.

Our future goals and actions in management, protection, and use of the Earth's natural resources must be approached with consideration of global conditions. As communication and transportation networks place us in closer contact with our global neighbors, it becomes increasingly clear that resource management decision we make, today and in the future, will not only affect the future generations of our own nation, but also those of other nations around the world.

SOCIO-ECONOMIC ASPECTS OF IPM IN SCANDINAVIA.

A. Bakke, Norwegian Forest Research Institute, Box 61, 1432 Ås-NLH, Norway.

If there is a danger that forests may be exposed to extensive insect damages, the Ministry of Agriculture may initiate the necessary public measures in order to counteract the attack, no matter who is the owner of the forest. The cost of such measures shall be covered by public funds. Helicopter is the only aircraft permitted used in forest. No application of pesticides or alternative control methods using either virus, bacteria or behavior modifying chemicals are permitted without the approval of the Ministry of agriculture. The most widespread IPM in Scandinavia is the control of a spruce bark beetle outbreak in Norway and Sweden in the late 1970es. The aggregation pheromone of the beetle was identified in 1977 and used as bait in more than a million traps deployed in the forests from 1979. The IPM included long-term objectives - to stimulate increased harvesting of overmature stands, among others by economic support to road constitution - and short-term measures - felling and removal of beetle-infested trees in addition to mass trapping. About 90 000 people, forest owners and persons employed in forestry, were involved in the campaign which was mainly financed by the government and stimulated by public information through advertising campaigns in newspapers, radio and television.

Insects Affecting Reforestation: Biology, Sampling, Damage Appraisal And Control

INSECTS AFFECTING IMMATURE FORESTS - WHY WE STUDY THEM AND WHAT CAN THEY DO TO US. P. Hall and D. Gilbert, British Columbia Ministry of Forests and Lands, Victoria, B.C., Canada.

Forestry is an important industry in British Columbia and in many other parts of the world. The long term economic and social benefits of this industry is dependent on a continuing production of desirable merchantable species. Insects can affect this production in various ways throughout the rotation and cause extensive disruption to both short and long term planning. Insects influencing plant establishment and growth to pole size must be considered in the initial site prescription and during the early stages of growth. Losses and damage by these pests affect the accomplishment of short term objectives and may ultimately have an impact on timber available at maturity.

USE OF TRUNCATED LIFE TABLES TO ASSESS IMPORTANCE OF FACTORS AFFECTING REFORESTATION, W.E. Waters*, College of Natural Resources, University of California, Berkeley, CA, USA 94720, and C.J. DeMars, USDA, Forest Service, Pacific Southwest Station, Berkeley, CA, USA 94704.

A record of injury and mortality in a life table format, based on 2-3 examinations a year, provides an excellent data base for analyses of the direct and interactive effects of insects, diseases, and other factors on survival of planted trees. The critical age interval(s), in terms of years or seasons, can be determined. Correlations of mortality with seedling source, age, and type, site features, site preparation, and other factors can also be assessed. Cohort life tables logically begin with time of planting, and may extend for 3 or more years depending on the age span of interest. Current, or horizontal, type ledgers may be constructed by including a range of age classes at the start. Analysis of variance and correlation techniques, trend analyses, k-factor analysis, and multiple regression analyses provide desired information.

Examples of the two approaches cited above are described: (1) a study of Douglas-fir seedling mortality in the North Coast region of California, covering the first 3 years following planting, and (2) a study of mortality of white pine in South Korea, including 5 age classes to 12 years.

SOME ASPECTS OF THE OCCURRENCE, BIOLOGY AND COLD-HARDINESS OF *HYLOBIUS* WEEVILS. A. Luik¹ and Kaljo Voolma², ¹Estonian Agricultural Academy, Rahu 5A-22, Tartu 202400, Estonian SSR, USSR; ²Estonian Research Institute of Forestry and Nature Conservation, Estonian SSR, USSR.

In Estonia, two species of pine weevils - *Hylobius abietis* L. (76.8% of the sample) and *H. pinastri* (23.2%) - are the most dangerous pests in conifer reforestation areas. *Hylobius pinastri* is more common in forest site types where spruces prevail. In spring, at the beginning of flight, males predominate; later, females are more numerous. In addition to stumps, logging slash not removed from clear-cut areas offers suitable conditions for the development of pine weevils. Population density of pine weevils was higher and development was faster in the piles where slash was raked up in spring and mixed with soil and ground litter than on stump roots. By the end of the summer of the first year, 60.8% of the weevils on pine branches and 23.3% of those on spruce branches had pupated or were newly emerged adults, whereas stump roots in the same cut area had only larvae. The mortality of pine weevils in the branch piles was higher than that on stump roots. Cold-hardiness of hibernating larvae was on the average -12°C, and was sometimes as low as -19°C, which guarantees successful hibernation under a deep snow covering.

THE USE OF ARTIFICIAL BAITS TO FORECAST SEEDLING DAMAGE CAUSED BY *HYLOBIUS ABIETIS* (COLEOPTERA: CURCULIONIDAE). Göran Nordlander, Division of Forest Entomology, Swedish University of Agricultural Sciences, P. O. Box 7044, S-750 07 Uppsala, Sweden.

Damage to conifer seedlings by adult weevils of the genus *Hylobius* is of considerable economic importance in reforestation areas in the Holarctic region. In Sweden, planting on clear-cuttings is commonly postponed for two or three years in order to avoid serious damage by *H. abietis* (L.), the most destructive species in this area. Insecticides and various mechanical devices are also used to protect seedlings. All these measures are costly; therefore a method for forecasting the risks of seedling damage in reforestation areas would be useful to forest managers.

The possibility to forecast seedling damage using an artificial bait attracting walking weevils was investigated in a field test including 9 adjacent clear-cuttings with differently sized populations of *H. abietis*. A strong positive correlation was found between seedling damage and the number of weevils caught in traps baited with the synergistic attractants α -pinene and ethanol. It was concluded that trapping during a five-day period prior to planting should be sufficient to predict relative damage risks for individual clear-cuttings within a region.

A SURVEY OF DAMAGE BY *HYLOBIUS ABIETIS* AND *HYLASTES* SPP. IN BRITAIN. Stuart Heritage, Sara Collins and Hugh F. Evans*. Forestry Commission, Northern Research Station, Roslin, Midlothian, EH25 9SY, U.K.

Details are given of the results from a survey of insect damage to nearly 4.5 thousand hectares of British restocking areas. Damage levels are compared with plant species and insecticide treatments.

FEEDING AND OVIPOSITION PREFERENCES OF PALES WEEVIL AMONG THREE CONIFEROUS HOSTS IN PENNSYLVANIA, U.S.A. E. Alan Cameron*, D. J. Shetlar and J. F. Boggs, Department of Entomology, Penn State University, University Park, PA, U.S.A.

Pales weevil, *Hylobius pales* (Herbst) (Coleoptera: Curculionidae), is a common pest in Christmas tree plantations in Pennsylvania. Tests were conducted in the laboratory, using freshly-cut host material, to determine whether adult weevils exhibit feeding or oviposition preferences among Scots pine (*Pinus sylvestris* L.), eastern white pine (*P. strobus* L.), and Douglas-fir (*Pseudotsuga menziesii* [Mirb.] [Franco]).

Preliminary tests demonstrated that, within a host species, feeding preferences did not exist among foliated branches of the five provenances of Scots pine, three provenances of eastern white pine, or three provenances of Douglas-fir tested. Neither was any discrimination observed when pairs of host species were presented simultaneously, or when all three species were exposed together. Adults at least 60 days old, which had completed their preoviposition and maturation feeding period, were presented with bole segments as oviposition substrates. When host material was presented from two species of trees at a time, Scots pine was preferred over both Douglas-fir and eastern white pine; Douglas-fir was preferred over eastern white pine. If material for all three trees was presented simultaneously, no discrimination was evident. Subsequent development was significantly less successful in Douglas-fir than in either of the other hosts.

Insects Affecting Reforestation: Biology, Sampling, Damage Appraisal And Control

ROOT BEETLES, STAND DISTURBANCE, AND MANAGEMENT OF BLACK-STAIN ROOT DISEASE IN PLANTATIONS OF DOUGLAS-FIR. J.J. Witcosky, USDA Forest Service, Forest Pest Management, George Washington National Forest, P.O. Box 233, Harrisonburg, VA USA 22801.

The root bark beetles *Hylastes nigrinus* (Coleoptera: Scolytidae) and *Pissodes fasciatus* and *Steremnius carinatus* (Coleoptera: Curculionidae) are vectors of *Ceratocystis* (*Verticicladiella*) *wageneri*, causal agent of black-stain root disease of Douglas-fir. Stand disturbance provides the link coupling host to vectors and pathogen and mediates the epidemiology of this root beetle--*C. wageneri* association. Disturbance agents may be environmental, biological, or anthropogenic. Forest management practices have intensified the disturbance regime of Douglas-fir forests; consequently, the root beetle--*C. wageneri* association is an emerging pest problem. A crop production/pest management system scheme is proposed. Opportunities for pest management are linked with the crop production system at times when pests enter the crop during forest management.

MINIMIZING *OTIORHYNCHUS* ROOT WEEVIL IMPACT IN CONIFER NURSERIES. D. Neilsen (USA)

No Abstract

BIOLOGY, OUTBREAK CHARACTERISTICS AND DAMAGE CAUSED BY THE BLACK ARMY CUTWORM (LEPIDOPTERA: NOCTUIDAE). L.M. Humble*, R.F. Shepherd, Canadian Forestry Service, 506 W. Burnside Road, Victoria, British Columbia, Canada, V8Z 1M5, and T.F. Maher, TFM Forestry Ltd., P.O. Box 364, Kamloops, British Columbia, Canada, V2C 5K9

The black army cutworm feeds on conifer seedlings causing mortality, dieback and deformity. Outbreaks occur 1 or 2 years after a site has been burnt. Larvae feed on herbaceous vegetation which regenerates after fire, and on interplanted seedlings when other vegetation has been depleted. Six parasites have been recovered from larval collections; one tachinid and two ichneumonids are quite abundant. The degree of damage is dependent on age and species of seedlings and amount of competing vegetation as well as cutworm population density. An outline of a management system for this problem is given which involves classifying site susceptibility, monitoring population density with pheromone traps, and manipulating time of planting.

BIOLOGY AND IMPACT OF WESTERN PINE SHOOT BORER, *EUCOSMA SONOMANA*, IN THE WESTERN UNITED STATES. L.L. Sower*, G.E. Daterman, and C. Sartwell. Pacific NW Research Sta., USDA Forest Serv., 3200 Jefferson Way, Corvallis, OR, USA 97331

Western pine shoot borer damages ponderosa, and other pines, by mining the pith of elongating terminal shoots, causing loss of about 25% of 1 year's vertical growth per attack. Some shoots are killed or weakened and lateral shoots may become dominant. Western pine shoot borer persists at low population levels, but 50% of leader shoots are commonly infested in plantations. Trees are first attacked at 5 to 10 years of age. After trees are 15 to 20 years old, 50% of terminal shoots are commonly infested. Females select the largest terminal buds for oviposition sites. Larval feeding then reduces growth to about that of average shoots. Thus, both infested and uninfested shoots attain about the same ultimate length. Adults mate early in the spring, and larvae enter the shoots shortly after bud-burst. In midsummer they bore exit holes, drop to the ground, pupate, and enter diapause. Insect development correlates with host development and with heat accumulation. Western pine shoot borer is atypical in that population levels are stable over most of a crop rotation and damage is chronic and inconspicuous. Treatment with synthetic pheromone reduces population levels 75%.

DAMAGE APPRAISAL AND MANAGEMENT OF THE WESTERN PINE SHOOT BORER, *EUCOSMA SONOMANA*, IN PLANTATIONS IN CALIFORNIA. C.B. Williams*, E.L. Smith and T.W. Koerber, United States Department of Agriculture, Forest Service, Berkeley, California 94701.

Studies examined: (1) The effects shoot borer attacks have on growth rates of ponderosa and Jeffrey pines in young plantations in California; and (2) The degree of suppression and recovery of shoot borer populations subjected to mating disruption treatments of one season and five consecutive seasons applied to these plantations. Shoot borer infestations began when the trees were approximately five years of age and 4.5 feet in height. Approximately 60 percent of the terminals were infested when the trees reached age 20. Trees comprising the tallest 50 percentile were attacked more frequently than trees in the shorter half of the plantations. Treatment effects on the frequency of infestation lasted two years. Treatments increased height growth up to 49 percent and volume growth up to 23 percent. Stand timber volumes were simulated for a rotation of 70 years using a PROGNOSIS growth and yield model. Using economic assumptions appropriate for local market conditions the present net benefits of the treatments ranged from a plus \$30.00 to a minus \$8.00 per acre. Single treatments applied to younger stands yielded the largest benefits.

SITE AND STAND RELATIONSHIPS AND INFLUENCES ON PINE TIP MOTH INFESTATION RATES. D. L. Kulhavy* and J. R. Meeker, School of Forestry, Stephen F. Austin State University, Nacogdoches, Texas, USA, 75962.

Pine tip moths (*Rhyacionia frustrana*, *R. rigidana* and *R. subtropica*) were sampled in 3-year old loblolly pine plantations, on sandy, loamy and clayey soil types in eastern Texas, USA. Infestations were highest on loamy sites followed by clayey and sandy sites. The sandy sites had the lowest nutrient levels and soil moisture content and the longest moisture stress period. The infestation rate was less than 8 percent of the total tips in 1985 and 1986. The clayey sites had the highest nutrient levels and soil moisture contents below 60 cm. Infestations were 11 percent in 1985 and 7.4 percent in 1986. On the loamy site, the host loblolly pines had moderate nutrient levels and soil moisture below 60 cm. Infestation rates were 20 percent in 1985 and 12 percent in 1986. Poor growth on sandy sites resulted in increased host tree deformation by tip moths. Moderate to vigorous growth on the loamy and clayey sites resulted in less deformation. Discriminant function analysis identified percent silt, foliar nutrients, and xylem moisture potential related to tip moth infestation rates.

Insects Affecting Reforestation: Biology, Sampling, Damage Appraisal And Control

INSECTS ASSOCIATED WITH THE INTENSIVE CULTURE OF PINUS ELLIOTTII AND P. TAEDA IN FLORIDA. J.L. Foltz, Department of Entomology & Nematology, University of Florida, Gainesville, Florida 32611 U.S.A.

Insect incidence and severity were observed for 3 years on trees in experimental plots receiving 4 combinations of intensive fertilization and weed control. Rhyacionia frustrana was the most common insect on P. taeda, infesting 90% of the trees on the untreated control (C) plots, 79% where there was weed control only (W), 77% for fertilizer only (F), and 77% on the combined (FW) treatment plot. R. subtropica infested relatively few P. elliotii with incidence rates ranging from 3% on W up to 12% on FW. Dioryctria amatella infested 2, 8, 6, and 26% of the trees in the C, W, F, and FW plots of P. elliotii and 0, 8, 6, and 17% of the trees on the P. taeda plots. None of the insects alone caused a significant amount of damage, but interactions with disease organisms killed and deformed enough trees to indicate possible pest problems if intensive fertilization and weed control were applied to large areas.

IMPACT OF PINE TIP MOTH CONTROL, WEED CONTROL AND FERTILIZER ON GROWTH AND FORM OF LOBLOLLY PINE. C.W. Berisford*, J.F. Godbee and D.W. Ross, Department of Entomology, University of Georgia, Athens, Georgia, USA 30602.

Height and diameter growth of loblolly pines 1-3 years old increased with intensity of management. Highest growth gains were realized with weed control, tip moth control and fertilizer combined. Highest single treatment gains occurred with weed control followed by tip moth control and fertilizer. Tip moth control significantly improved tree form and trees were 10-15 percent taller than untreated trees.

EVIDENCE FOR PINE TIP MOTH (RHYACIONIA SPP.) RESISTANCE IN LOBLOLLY PINE (PINUS TAEDA L.). S.C. Cade*, Weyerhaeuser Co., Hot Springs, AR 71901, and Roy L. Hedden, Dept. of Forestry, Clemson University, Clemson, SC 29631, USA.

Replicated 24-tree plots of 12 half-sib families (one family per plot) were planted in 6 locations in newly site-prepared ground in eastern North Carolina (USA) between 1984 and 1986. Split plots were created by protecting one-third of the trees from tip moth with carbofuran or fenvalerate insecticide applications. Terminal and lateral shoot damage and growth increment were measured by individual growth flush at the end of each of the 3 tip moth generations for the first 2 growing seasons. Analysis of variance showed that significant differences in height increment among families were evident, only when growth increment was partitioned by time periods corresponding to each insect generation. Growth differences among families were most significant for the first generation period (through mid-June), during which time approximately 60% of the annual increment occurred. Significant negative correlation coefficients (ranging from -.50 to -.82) between: (1) annual growth increment, and (2) tip moth infestation level for the 1st generation were found in 5 of the 6 locations. Three of the 12 families showed consistent indications of resistance as evidenced by: (1) low 1st generation tip moth infestation levels; and (2) low percent growth loss in unprotected trees, when compared to protected trees.

SEASONAL FLUCTUATION OF HYPSIPYLA GRANDELLA ZELLER (LEPIDOPTERA: PYRALIIDAE) POPULATION ON YOUNG PLANTATION OF MELIACEAE SPECIES IN THE REGENERATION EXPERIMENTAL FOREST IN PERUVIAN AMAZON. S. Yamazaki, T. Ikeda, K. Fukuyama*, A. Taketani, K. Fujita, Forest Protection division, Forestry & Forest Products Research Institute, Ibaraki, 305 Japan and C. Vasquez, INFOR A/C CENFOR apartado, #201 Pucallpa, Peru.

Hypsipyla grandella is the most harmful shoot borer of against Meliaceae species in tropical region. The young plantations in the experimental forest of the Forest Regeneration Experiment Project in Peruvian Amazon under the foreign aid program of JICA have been damaged by this species since 1983. Population dynamics and ecological studies of H. grandella have been investigated from 1985.

The population densities of H. grandella increased during rainy season, from November to April and decreased during dry season, from May to October. The food sources for this species also increased in rainy season and decreased in dry season. The main mortality factors of H. grandella was not cleared, but several parasitic wasps, a nematode and several predacious wasps observed in the field may play an important role to regulate the population density as well as the amounts of host plants.

IMPACT OF LONCHAEA CORTICIS ON BROODS OF PISSODES STROBI IN PICEA SITCHENSIS. M.A. Hulme* and J.W.E. Harris, Pacific Forestry Centre, 506 West Burnside Road, Victoria, B. C., Canada V8Z 1M5.

Broods of Pissodes strobi in leaders of Picea sitchensis were subject to predation by Lonchaea corticis during the summer before adult weevils emerged in the fall, and during the winter before the remaining weevils matured to adults in spring. Regression analysis on data collected in the fall showed that adult P. strobi production was negatively correlated with number of L. corticis larvae. Furthermore there was a threshold number of L. corticis larvae above which no P. strobi adults were produced. Most immature weevils remaining in the leaders in the fall disappeared during the winter without any external signs on the leader. Laboratory tests simulating either summer or mild winter conditions showed that P. strobi larvae and pupae easily survived these conditions, but when L. corticis larvae were present weevil pupae were readily eaten.

EFFECT OF RED ALDER OVERSTOREY ON THE OCCURRENCE OF PISSODES STROBI PECK DURING THE ESTABLISHMENT OF A SITKA SPRUCE PLOT. J.A. McLean, Faculty of Forestry, University of British Columbia, 2357 Main Mall, Vancouver, B.C. Canada V6T 1W5

In 1980, 1/0 and 2+1 Sitka spruce seedlings were planted in a cleared area and also under an adjacent red alder overstorey at the UBC Research Forest. The growth of the trees has been closely monitored with special note being taken of attacks by the white pine weevil, Pissodes strobi Peck. The first attack by P. strobi was recorded in 1982, during the third growth season. By 1987, 23% of the spruce growing under the alder were attacked, two for the second time. Meanwhile, 50% of the spruce growing in the open were attacked, 23 for the second time. The utility of overstorey management to reduce the impact of P. strobi will be discussed.

Insects Affecting Reforestation: Biology, Sampling, Damage Appraisal And Control

IMPACT OF THE SITKA SPRUCE WEEVIL, *PISSODES STROBI* (PECK), ON LOG YIELD OF SITKA SPRUCE. R.I. Alfaro. Canadian Forestry Service, Pacific Forestry Centre, Victoria, B.C. Canada. V8Z 1M5.

Based on 10 years of weevil damage data, an interactive computer program was written to simulate the effects of repeated destruction of the leaders of Sitka spruce (*Picea sitchensis* (Bong) Carr) by the Sitka spruce weevil (=white pine weevil) (*Pissodes strobi* (Peck)), on tree form, and log yield. Some of the main features of the model as well as some of the results are presented.

GROWTH LOSS IN SAPLING PONDEROSA PINE ASSOCIATED WITH GOUTY PITCH MIDGE-CAUSED INJURY. W.D. Bedard*, A.S. Robertson and G.T. Ferrell, Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture, Berkeley, California, USA 94701.

In a case history using paired-comparison tests of annual height growth and shoot injury, growth loss in sapling ponderosa pines in northern California was associated with injury caused by the gouty pitch midge. Trees with resinous surfaces on their elongating spring shoots were repeatedly injured by the midge. Of three different expressions used to compare height growth of midge-injured and uninjured trees, internode length was judged most appropriate because its results were simplest to interpret.

GEOGRAPHIC VARIATION IN *PINUS PONDEROSA* SUSCEPTIBILITY TO THE GOUTY PITCH MIDGE, *CECIDOMYIA PINNIOPSIS*, IN THE SIERRA NEVADA AND SOUTHERN CASCADE MOUNTAINS OF CALIFORNIA. G.T. Ferrell*, W.D. Bedard and R.D. Westfall, United States Department of Agriculture, Forest Service, Berkeley, California 94701.

Geographic variation in susceptibility to the gouty pitch midge (GPM) was analyzed in 3-year-old ponderosa pine seedlings in an outdoor nursery in the central Sierra Nevada. Represented were 472 families of phenotypically superior, wind-pollinated seed trees from the species range in the Sierra Nevada and southern Cascade Mountains of California. Trees with viscid (resinous) spring shoot surfaces generally sustained a much higher frequency of GPM injuries than those with nonviscid (smooth or waxy) surfaces. Susceptibility was based on mean family scores for shoot surface and GPM injury. Analysis of these in relation to latitude, longitude, and elevation of the seed source revealed a complex geographic pattern. Susceptibility of families from the northern Sierra Nevada and southern Cascades was relatively low and increased only moderately at the northern, eastern, and southern margins of the region. In the southern Sierra Nevada, susceptibility was higher and increased with decreasing latitude. Longitudinal trends in susceptibility to GPM were not evident in this region.

THE BIOLOGY AND WITHIN-TREE DISTRIBUTION OF THE SPRUCE BUD MIDGE, *RHABDOPHAGA SWAINEI* FELT (DIPTERA: CECIDOMYIIDAE), ON BLACK SPRUCE IN NEWFOUNDLAND WITH NOTES ON HOST DAMAGE. R.J. West, Newfoundland Forestry Centre, Canadian Forestry Service, Box 6028, St. John's Newfoundland, Canada A1C 5X8.

R. swainei has one generation a year on black spruce in Newfoundland. Newly hatched larvae enter bud primordia of flushing shoots in late June and early July and larvae mature by fall to overwinter within buds. Pupation occurs within buds the following spring and adults emerge in June. The number of eggs dissected from virgin females averaged 86. *Platygaster rhabdophagae* MacGown (Platygasteridae), *Mesopolobus* sp. (Pteromalidae), *Torymus* sp. (Torymidae) and *Tetrastichus* sp. (Eulophidae) were responsible for high parasitism levels. Terminal buds were attacked significantly more than lateral or uppermost lateral bud types and most infested buds were in the top third of the crown. There was no significant difference in the number of infested buds in north, east, south and west quadrants of tree crowns. An apical meristem never developed in infested buds and buds did not flush. The *R. swainei* larva redirects the growth of primordial cells in the host shoot to produce gall tissues which serve to provide it with a source of nutrient and overwintering shelter. The overall impact of the midge on tree growth is a slight reduction in leader growth in the year of a terminal bud attack, however, leader growth returns to normal the following year.

THE PINE GALL MIDGES, *THECODIPLOSIS BRACHYNTERA* AND *CONTARINIA BAERI* (DIPTERA: CECIDOMYIIDAE), IN YOUNG PINE STANDS IN NORTHERN GERMANY: BIOLOGY, OUTBREAKS AND ECONOMIC IMPORTANCE. K. Winter (FRG)

No Abstract

POTENTIAL NEW PRODUCTS FOR THE CONTROL OF THE TEXAS LEAF-CUTTING ANT, *ATTA TEXANA*. R. S. Cameron. Forest Pest Control Section, Texas Forest Service, Lufkin, Texas, USA 75901.

The Texas leaf-cutting ant, *Atta texana*, causes serious damage to pine plantations in Texas and Louisiana. Methods currently available in the USA for control are either ineffective or dangerous to use. Numerous toxic baits have been screened in Texas for leaf-cutting ant acceptance and eleven of these containing either hydramethylnon, avermectin B₁, or fenoxycarb were field tested for efficacy. A thermal fog treatment containing resmethrin was also tested. Three hydramethylnon baits formulated on citrus pulp and two on corn grit carriers effectively controlled leaf-cutting ant colonies. The baits containing avermectin B₁ and fenoxycarb were ineffective. An effective application method and rate were developed for the resmethrin thermal fog.

Insects Affecting Reforestation: Biology, Sampling, Damage Appraisal And Control

EFFECTS OF CRUDE AQUEOUS NEEM EXTRACTS ON DEFOLIATION OF KHAYA NYASICA BY HETERONYGMIA DISSIMILIS (LEPIDOPTERA: LYMANTRIIDAE) IN EAST AFRICA. A. K. Rwamputa and H. G. Schabel*, Faculty of Forestry, P.O. Box 3009, Sokoine University of Agriculture, Morogoro, Tanzania.

An outbreak of the mahogany defoliator Heteronygmia dissimilis at Morogoro, Tanzania, prompted an investigation of, among other aspects, potential controls for this insect by locally available means.

As a result, boiled and unboiled crude aqueous extracts obtained from pulverized foliage (1% conc.) and seed kernel (0.5 and 1.0%) of the neem tree, Azadirachta indica, were applied to foliage of mahogany and offered to first, second and last instar larvae of H. dissimilis under laboratory conditions. Feeding response was monitored by way of leaf areas consumed.

Neem kernel extracts at the 1.0% conc. afforded complete protection against defoliation by all instars. The 0.5% seed kernel and 1% leaf extracts offered only partial protection, i.e. about 2/3 and 1/3, respectively, with decreases of efficiency against later instars. Boiling of extracts increased foliar protection slightly.

EFFECTS OF THE YELLOW-SPOTTED PINE WEEVIL, PISSODES NITIDUS ROELOFS, ON KOREAN PINE PLANTATIONS IN NORTHEAST CHINA. Jin Liyuan, Forest Research Institute, Yichun, Heilongjiang Province, People's Republic of China.

The yellow-spotted pine weevil, Pissodes nitidus Roelofs, is a serious pest of terminals of young Korean Pine, Pinus koraiensis Sieb. and Zucc., in Northeast China. Up to 20% of stand volumes can be lost after 2-4 repeated attacks with 0.25-0.33 m of height loss resulting for each attack. Heat sum requirements for each life stage have been computed. More than 50 species of parasitoids have been reared from infested leaders of Korean Pine. Most are members of the Chalcidoidea and the Ichneumonoidea. The major parasites have three generations/year and hibernate as mature larvae. Strategies for management of P. nitidus infestations including leader clipping, parasite enhancement and pesticides will be discussed.

EFFECTS OF DEFOLIATION, DECAPITATION AND PARTIAL GIRDLING ON ROOT AND SHOOT GROWTH OF PINE AND SPRUCE SEEDLINGS. B. Långström* and C. Hellqvist, Section for Forest Entomology, Swedish University of Agricultural Sciences, S-77073 Garpenberg, Sweden.

One-year-old seedlings of Scots pine (Pinus sylvestris L.) and Norway spruce were defoliated, decapitated or girdled partially in order to simulate different types of insect damage. Immediate growth effects were evaluated in a growth chamber. Another set of seedlings treated in a similar way were planted in a nursery and growth was monitored for two growing seasons.

Seedling survival was high, except for the partially girdled spruce seedlings. For both species, total defoliation or partial girdling drastically reduced root growth during the first weeks after the treatment. This effect was still present after the first field season. After two field seasons, decapitated or defoliated pines were still smaller than the controls whereas all spruces and the partially girdled pines had recovered. The results were interpreted in terms of growth patterns and carbohydrate availability, and the impact of different types of insect damage on planting success and stand establishment was discussed.

A STUDY OF THE MORPHOLOGY AND BIOLOGY OF CINARA PINIKORAIENSIS (Homoptera: Lachnidae) Fang San yang, Northeast Forestry University Harbin, People's Republic of China

The biology of Cinara pinikoraiensis is described and its morphology compared with that of C. pinea, C. cembrae and C. shinjii.

New Approaches To Forest Insect Control: A Case Study Using *Bacillus thuringiensis*

THE RELATIONSHIP OF FOLIAR DEPOSIT OF *BACILLUS THURINGIENSIS* TO THE MORTALITY OF EASTERN SPRUCE BUDWORM, *CHORISTONEURA FUMIFERANA* CLEM. Paul G. Fast (retired)* and A. Sundaram, Forest Pest Management Institute, Canadian Forestry Service, P.O. Box 490, Sault Ste. Marie, Ontario, Canada P6A 5M7.

Laboratory bioassays of *Bacillus thuringiensis* (Bt) formulations deposited on balsam fir foliage in droplets of defined size were used to evaluate the effect of drop size, droplets/needle and concentration on mortality of eastern spruce budworm, *Choristoneura fumiferana* Clem., placed on the shoots. The data showed that the concentrations being recommended for operational application at the time of these bioassays was too low. Concentrations of Bt in realistic foliar deposits that produce an LD₈₀ or a minimized LT₅₀ can guide the experimenter to the lowest concentrations likely to be effective in the field thereby minimizing the number of expensive field trials required for optimization.

DEVELOPMENT OF DEPOSIT/EFFICACY REGRESSIONS FOR ULV APPLICATIONS OF *BACILLUS THURINGIENSIS* AGAINST SPRUCE BUDWORM. C.J. Wiesner*, Research and Productivity Council, Fredericton, New Brunswick, Canada E3B 5H1; P.G. Fast, Canadian Forestry Service, Sault Ste. Marie, Ontario, Canada P6A 5M7; E.G. Kettela, Canadian Forestry Service, Fredericton, New Brunswick, Canada E3B 5P7.

Aerial application of insecticides in forestry has long been associated with highly variable efficacy, particularly with *Bacillus thuringiensis*. Detailed studies of spray deposits on target foliage documented very large variation in deposit both within blocks and between blocks. Foliar deposits did not correlate well with ground level deposits on cards. Clearly, evaluation of efficacy must be based on actual foliar deposit. This paper describes the development and validation of techniques for measuring foliar deposit of B.t. in individual sample trees and correlation with reduction in defoliation and larval survival on those trees. Natural within block variability provided a 100X range of deposits which were strongly correlated with efficacy. These techniques have provided the means for rigorous evaluation of insecticide formulation performance in actual field applications.

INVESTIGATION OF THE RELATIONSHIPS BETWEEN SPRAY EFFICACY AND FOLIAR DEPOSIT OF *BACILLUS THURINGIENSIS* KURSTAKI APPLIED AERIALY AGAINST LARVAE OF *CHORISTONEURA FUMIFERANA* CLEM (LEPIDOPTERA: TORTRICIDAE). E.G. Kettela*, Canadian Forestry Service-Maritimes, P.O. Box 4000 Fredericton, New Brunswick, E3B 5P7, C.J. Wiesner, New Brunswick Research and Productivity Council, P.O. Box 6000 Fredericton New Brunswick and P.G. Fast (Retired), Forest Pest Management Institute, P.O. Box 490, Sault Ste. Marie Ontario, Canada, P6A 5M7.

To improve the efficacy of aerially applied pesticides it is essential to understand the relationship between spray deposition on foliage and efficacy. Comparison of spray applications on the basis of application rate alone (i.e. g/ha) is not sufficient due to the high degree of variability of deposit between samples. Aerial spray trials with commercial preparations of *Bacillus thuringiensis* K. were conducted to first test and validate a spray deposit measuring system, then to relate deposit to efficacy (reduction in defoliation and insect survival) on a tree by tree basis. The results of this study demonstrate the relationship between spray deposit and efficacy against *C. fumiferana*. Improved spray efficiency is suggested through the use of ultra low volume sprays and high potency *B. thuringiensis* products

IMPLEMENTATION OF ULTRA LOW VOLUME STRATEGY FOR CONTROL OF SPRUCE BUDWORM (*CHORISTONEURA FUMIFERANA*, CLEM.). H. J. Irving, Forest Protection Limited, Fredericton, New Brunswick, Canada E3B 5C2.

Ultra Low Volume (ULV) applications of chemical insecticides have been utilized successfully for many years in limiting defoliation by the eastern spruce budworm on susceptible conifer forests in New Brunswick. Recently Ultra Ultra Low Volume (UULV) applications - 0.4 litres per hectare of total formulation - have also resulted in equally successful protection.

The biological insecticide, *BACILLUS THURINGIENSIS* (Bt.), was first applied experimentally by Forest Protection Limited (FPL) in cooperation with the Canadian Forestry Service in 1962 with indifferent results. In recent years, commercially available Bt. formulations, fully registered in Canada, have undergone major improvements.

FPL now applies undiluted commercial Bt. formulations through rotary atomizers at 2.4 litres, containing 30 Billion International Units (B.I.U.'s) per hectare. As more concentrated formulations receive registration, it is anticipated that equivalent foliage protection can be achieved through the UULV strategy with reduced rates such as 15 B.I.U.'s/hectare. Experimental trials have indicated that this is possible.

ULTRA-LOW-VOLUME APPLICATION OF UNDILUTED *BACILLUS THURINGIENSIS* AGAINST THE GYPSY MOTH. K. van Frankenhuyzen*, Canadian Forestry Service, Sault Ste. Marie, Ont, Canada, E. A. Cameron, Department of Entomology, Penn State University, University Park, PA, USA, C. Riley and C. Wiesner, NB Research and Productivity Council, Fredericton, NB, Canada.

For aerial control of defoliators on conifers, it is more effective and less expensive to use low volumes of undiluted B.t. than high volumes of diluted material. ULV application requires atomization into small droplets to ensure adequate spray coverage. We assessed the feasibility of this technique for gypsy moth control by studying spray deposition in an oak forest canopy in relation to spray volume (1.7 to 7.0 L/ha) and droplet size, and by comparing the effectiveness of small and large droplets.

Low volume application resulted in more uniform spray deposition because the smaller droplets were more effective in penetrating the canopy. Small droplets of undiluted B.t. caused higher mortality of gypsy moth larvae in foliage bioassays than large drops of diluted material. Application of undiluted B.t. at 40 BIU/ha in 2.3 and 3.1 L/ha resulted in equivalent or better foliage protection and population reduction than application of the same material diluted to 7.0 L/ha. Effective control of gypsy moth is thus possible at much lower treatment costs by using ULV application of undiluted B.t.

ULTRA-LOW-VOLUME APPLICATION OF *BACILLUS THURINGIENSIS* AGAINST THE WESTERN SPRUCE BUDWORM IN NEW MEXICO. A.H. Smith and J.O. Johnsen (USA)

No Abstract

A DEMONSTRATION OF HOST ATTRACTION IN *IPS PINI* (SAY) (COLEOPTERA: SCOLYTIDAE) IN IDAHO. S.J. Gast*, M.W. Stock and M.M. Furniss, University of Idaho, Moscow, Idaho 83843

Two consecutive generations of the pine engraver, *Ips pini* (Say), were studied to determine response to natural ponderosa pine host odors in Idaho. Response was measured on a laboratory olfactometer. Beetles were then examined for physiological condition and physical factors. Nearly 14% of males tested were attracted to host volatiles; 10% of females tested responded positively. These host-responding beetles were characteristically desiccated and had air in their ventriculus. Both of these conditions result from post-emergence activity, particularly flying. Factors not significantly related to host response were beetle size, abundance of phoretic mites and parasitic nematodes, relative abundance of fat bodies, and ambient barometric pressure. This study demonstrates host attraction in *Ips pini* and describes the physical condition of host-responding beetles.

HOST TREE SUSCEPTIBILITY, SUITABILITY, AND UNSUITABILITY RECOGNIZED BY SOME EUROPEAN BARK BEETLES

John A. Byers, Department of Ecology, University of Lund, S-223 62 Lund, Sweden.

The host tree susceptibility to attack and colonization is recognized by the European pine shoot beetle, *Tomicus piniperda*, by an olfactory perception of host monoterpenes ((+/-)-alpha-pinene, (+)-3-carene, and terpinolene) in wound oleoresin. The host suitability is also recognized by the same olfactory perception mechanism. The host suitability (selection) of Norway spruce is recognized, at least in part, by the six-toothed European spruce bark beetle, *Pityogenes chalcographus*, by means of host monoterpenes ((+/-)-alpha-pinene, camphene, and (-)-beta-pinene) interacting with pheromone components (chalcogran and the recently identified methyl decadienoate). Recognition of the unsuitability of a formerly suitable host by *T. piniperda* is mediated by olfactory perception of verbenone released from infested Scots pine substrates.

NEW SEMIOCHEMICALS IN THE PINE ENGRAVER, *IPS PINI* (SAY) (COLEOPTERA: SCOLYTIDAE). G. Gries*, D.R. Miller, M.J. Smirle and J.H. Borden, Centre for Pest Management, Department of Biological Sciences, Simon Fraser University, Burnaby, B.C., Canada V5A 1S6

In captured volatiles from *I. pini* boring into logs of lodgepole pine, 2 new pheromones were disclosed. When combined with the known pheromone Ipsdienol one increased the attractiveness, and the other, (E)-myrcenol, inhibited the beetles' response. (E)-myrcenol is the first antiaggregation pheromone identified in the genus *Ips*.

SEASONALITY OF PHEROMONE SPECIFICITY IN *IPS PINI* (COLEOPTERA: SCOLYTIDAE).

S.A. Teale* and G.N. Lanier, Dept. of Environ. and Forest Biol., SUNY, Coll. Environ. Sci. and Forestry, Syracuse, New York 13210.

A New York population of *Ips pini* failed to respond to synthetic ipsdienol during the spring and early summer. At the same time, natural sources were attractive. From mid-August to mid-September, natural odors and synthetic racemic ipsdienol were equally attractive. Laboratory reared beetles respond well to beetle volatiles but not to synthetic ipsdienol nor a blend of a female frass extract and ipsdienol. It appears that during the period when beetles attack hosts, they use an unknown male-produced pheromone, but late in the season when beetles normally emerge to overwinter in the litter but do not normally attack hosts they are responsive to racemic ipsdienol.

INCIPIENT PREMATING BARRIERS TO REPRODUCTIVE ISOLATION IN TWO SIBLING *IPS* SPECIES (COLEOPTERA: SCOLYTIDAE) FROM SOUTHERN CALIFORNIA: MISCEGINATION PERSISTS. J.W. Fox*, D.L. Wood and J.H. Cane, Department of Entomological Sciences, University of California, Berkeley, CA 94720.

Host and conspecific discrimination were tested as reproductive isolating mechanisms between *Ips paraconfusus* infesting Coulter pines (*Pinus coulteri*) and *I. confusus* infesting pinyon pines (*P. monophylla*). In allopatric areas, we induced pheromone production in host and nonhost logs using conspecific and hetero-specific males. The propensity of these female sibling bark beetle species to join heterospecific and conspecific males introduced into host and nonhost in allopatric areas was tested. Females joined male galleries in all treatment combinations in each species area. *I. paraconfusus* females joined both hetero-specific and conspecific males tunneling in both tree species in each area. *I. confusus* females failed to join *I. paraconfusus* males in Coulter pine, but joined *I. paraconfusus* in pinyon pine. Complete sympatry was shown at Lake Baldwin when females of both sibling species joined conspecific males in their hosts. Males attacked all four beetle/host treatment combinations in both areas. Host and/or conspecific discrimination do not appear to be premating reproductive isolating mechanisms in these areas.

ASPECTS OF THE CHEMICAL ECOLOGY OF *IPS LATIDENS* (LECONTE). S.J. Seybold*¹, D.L. Wood¹, K.Q. Lindahl², R.M. Silverstein³, and J.R. West³.

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Collections and bioassays of compounds associated with tunneling male *Ips latidens* indicated that this insect is attracted to both host compounds and the beetle-associated compound, ipsenol. Surprisingly, the beetle-associated compound is absent in some collections. Sequential fractionation and bioassay were employed to analyze host attractants in a collection devoid of ipsenol. Treatments in the bioassay were analyzed using a sequential statistical test. A pheromone collection experiment that attempts to control for differences in population origin, host of origin, host of aeration, and physiological state/generation of the insect was performed to identify which variables might have bearing on the presence of ipsenol.

CHEMICAL SIGNALS AND MALE MATING STRATEGIES IN SCOLYTIDAE. T.W. Phillips, Entomology and Nematology Department, 3103 McCarty Hall, University of Florida, Gainesville, FL 32611

The roles of pheromones used by male bark beetles differ with the mating system employed. Chemical signaling was studied and compared in two pine-infesting species: the monogynous *Dendroctonus terebrans* (Olivier) and the harem polygynous *Ips calligraphus* (Germar). Male *D. terebrans* locate mates at oviposition sites and produce *exo-brevicomin*, which inhibits response of other males to the female-produced attractant. Males reside with females in galleries for up to 20 days, past the oviposition time. Up to 90% of in-flight females were found to be mated. Chemical and physical mate-guarding by male *D. terebrans* is interpreted as a strategy for maximizing fitness by last-mating fertilizations.

I. calligraphus males select suitable hosts and produce pheromones that attract females and opportunistic males. Fecundity and brood production were previously shown to be correlated with host phloem thickness. Field tests demonstrated that male *I. calligraphus* boring in pine bolts with thick phloem (2-3 mm) were more attractive than males boring in bolts with thin phloem (0.5-1.5 mm). Stronger signaling by males on thick phloem would help ensure their acquisition of larger harems and thus maximize the number of progeny sired.

HYBRIDIZATION BARRIERS IN GROUP IX IPS: *I. HOPPINGI* LANIER AND *I. CONFUSUS* (LECONTE) (COLEOPTERA: SCOLYTIDAE). L.D. Merrill*, D.L. Wood and J.H. Cane, Department of Entomological Sciences, University of California, Berkeley, CA 94720, USA.

Two populations of *I. hoppingi* and one of *I. confusus* were hybridized to test for postmating inviability. Experimental matings were conducted in the three hosts of these populations, *Pinus remota* (Little) Bailey and Hawksworth, *P. discolor* Bailey and Hawksworth, and *P. edulis* Engelm., respectively. Premating behaviors were quantified after two weeks' development, galleries were dissected and measured and immatures counted. Adult female beetles were dissected to determine insemination status. Paleobotanical records indicate that the population of *I. hoppingi* in *P. remota* has been widely disjunct from the other two populations for 10,000 years. The *I. hoppingi* population in *P. discolor* and the *I. confusus* population in *P. edulis* are parapatric, permitting interactions in present time.

AGGREGATION PHEROMONE OF THE FOUR-EYED SPRUCE BARK BEETLE, POLYGRAPHUS RUFIPENNIS KIRBY (COLEOPTERA: SCOLYTIDAE). W.W. Bowers*, Newfoundland Forestry Centre, Canadian Forestry Service, Box 6028, St. John's, Newfoundland, Canada A1C 5X8. J.H. Borden and G. Gries, Centre for Pest Management, Department of Biological Sciences, Simon Fraser University, Burnaby, British Columbia, Canada V5A 1S6.

Evidence for secondary attraction in the four-eyed spruce bark beetle, *Polygraphus rufipennis* Kirby, was obtained in field attraction studies using "greenhouse" cages on which glass barrier traps were erected. Cages baited with male-infested logs caught significantly more beetles than cages with female-infested logs and uninfested control logs. In the laboratory, an open arena, airflow olfactometer was used to test the response of adults to various volatile stimuli. Both sexes responded to the odor of male-produced frass. Analysis of Porapak Q-captured volatiles disclosed that males produce 3-methyl-3-buten-1-ol as the aggregation pheromone. In field tests *P. rufipennis* responded to trees and multiple funnel traps baited with synthetic 3-methyl-3-buten-1-ol. The aggregation pheromone also elicited a kairomonal response by *Lasconotus intricatus*, an entomophagous enemy of the four-eyed spruce bark beetle.

RELATIONSHIPS BETWEEN INDEXES OF TREE VIGOUR AND THE INDUCED DEFENSE REACTION OF SCOTS PINE TO A FUNGUS ASSOCIATED WITH *IPS SEXDENTATUS* (COLEOPTERA: SCOLYTIDAE). François Lieutier* and George T. Ferrell, (FL) INRA. Zool. Forest., Ardon 45160, Olivet, France; (GTF) SWFRES, USDA, PO Box 245, Berkeley, California 94720, USA.

In July 1986, 20 young (30-40 year) and 20 old (80-100 year) pines were twice inoculated with *Ceratocystis brunneo-ciliata* in Fontainebleau and Orléans Forests (France). Eight days after, the intensity of the defense reaction was appreciated by the length of the defense reaction in the phloem, its resin concentration and the percentage of phloem sieve cells filled with resin. The vigour of each tree was simultaneously appreciated by crown characteristics (class, raggedness, ...), growth indexes (efficiencies, P.G.R.,...) and shigometer measurements. Crown conditions and shigo-measurements were not correlated with the intensity of the defense reaction. A significant negative correlation was found between growth efficiencies and the reaction. The most productive trees had the lowest defense reaction. In addition, the old trees were more reactive than the young ones. The growth-differentiation balance concept could suggest an explanation: increment cores were taken in the trees in July 1986 and after the growth of 1986 was completed. The most reactive trees in July seemed to be those having the highest ratio "growth 86 in July/total growth of 86". These results will be discussed in relation with the possible defense strategies of pines against bark beetle attacks.

MECHANISM OF TRANSMISSION OF THE PATHOGENIC BLUE-STAIN FUNGUS, OPHIOSTOMA POLONICUM, BY IPS TYPOGRAPHUS IN NORWAY SPRUCE. M.M. Furniss*, H. Solheim and E. Christiansen, Department of Plant, Soil and Entomological Sciences, Univ. of Idaho, Moscow, ID 83843 and Norwegian Forest Research Institute, Ås-NLH, Norway.

Ips typographus is demonstrated to transmit the pathogenic blue-stain fungus, *O. polonicum*, to Norway spruce. SEM photos show spores of this and other fungi in pits on the pronotum and elytra. Inoculation of stem sections with dissected parts of beetles produced staining characteristic of *O. polonicum*. Malt agar cultures of body parts and of blue-stained xylem resulting from inoculation with body parts, confirmed the presence of *O. polonicum*. Frequency of transmission was high for the head, prothorax and elytra, individually.

THE ROLE OF THE AMBROSIA BEETLE, PLATYPUS SUBGRANOSUS SCHEDL AS AN INDICATOR OF INFECTION OF MYRTLE, NOTHOFAGUS CUNNINGHAMII (HOOK.) OERST. BY THE PATHOGENIC FUNGUS, CHALARA AUSTRALIS WALKER AND KILE IN TASMANIAN RAINFOREST. H.J. Elliott*,¹ R. Bashford¹, S. Candy¹ and G.A. Kile².

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The pathogenic fungus, *Chalara australis* causes the disease myrtle wilt in myrtle, *Nothofagus cunninghamii* the dominant tree species in Tasmanian cool temperate rainforest. Surveys have shown that cumulative mortality of the myrtle component of rainforest averages 24% in undisturbed stands.

Attack by the ambrosia beetle *Platypus subgranosus* is a reliable indicator of infection of *N. cunninghamii* by *C. australis*. Analysis of the distribution of *P. subgranosus* attack on individual stems showed a strong correlation with sapwood infected with *C. australis* when no externally visible signs of infection were present.

When mature healthy *N. cunninghamii* were stressed by various treatments to promote favourable conditions for attack by *P. subgranosus* most attacked trees were found to have a prior infection of *C. australis* as a result of the imposed stress. The relationship between *P. subgranosus* and *C. australis* is discussed in the context of the spread of myrtle wilt in disturbed and undisturbed rainforest.

HOST EFFECTS ON THE POPULATION GENETICS AND DYNAMICS OF THE MOUNTAIN PINE BEETLE, DENDROCTONUS PONDEROSAE HOPKINS (COLEOPTERA: SCOLYTIDAE). D.W. Langor, Department of Entomology, University of Alberta, Edmonton, Alberta, Canada T6G 2E3.

The objective of this study was to determine if host preference results in genetic differentiation of sympatric mountain pine beetle (MPB) populations in lodgepole (LPP) and limber (LMP) pine in SW Alberta and if such genetic variation is correlated with differences in (1) beetle morphology, (2) population dynamics, and (3) fecundity and fertility in cross-breeding experiments. Genetic structure of MPB populations was studied as isozyme variation using electrophoresis. Significant genetic divergence associated with host use was detected at one site. This suggests preferential selection of tree species by beetles and/or differential natural selection due to host mediated mortality within the two host species. Beetles from the two hosts did not differ significantly for any of the 12 morphological characters measured. Controlled breeding studies revealed some differences in MPB reproductive success, fecundity, mortality and development associated with host use but there was no evidence of any barriers to gene flow between the two populations. Significant differences in beetle phenology associated with host use were not detected in field studies. Controlled breeding and field studies indicated that LMP was a better host for MPB fecundity, development and survival suggesting that MPB populations in this host species have the potential to build up faster than in LPP. Since there is no apparent barrier to prevent LMP beetles from invading, under the right conditions, the commercially valuable LPP stands, LMP stands may serve as foci for MPB outbreaks.

PITYOPHTHORUS ORARIUS BRIGHT (COLEOPTERA: SCOLYTIDAE) IN A DOUGLAS-FIR SEED ORCHARD: EFFECT OF CLONAL SOURCE AND CONE CROP ON RATE OF ATTACK. N. G. Rappaport, USFS Pacific SW Station, P.O. Box 245, Berkeley, CA 94701 USA and D. L. Wood, Department of Entomological Sciences, University of California, Berkeley 94720 USA.

The geographic range of the Douglas-fir twig beetle, Pityophthorus orarius Bright, has been greatly extended. A survey of Douglas-fir (Pseudotsuga menziesii [Mirb.] Franco) trees in a northern California seed orchard revealed that those bearing especially heavy cone crops were significantly more likely to be infested by twig beetles than were those bearing light crops. A highly significant association was found between clonal source and attack rate. A second survey was conducted incorporating an index of tree vigor in order to assess its relationship with cone crop and clone. The inter-relationships of these variables and their value in predicting twig beetle attack rates will be reported.

DISTRIBUTION OF BARBARA COLFAXIANA (KEARFOTT) (LEPIDOPTERA:TORTRICIDAE) EGGS IN DOUGLAS-FIR AND A METHOD FOR ESTIMATING EGG DENSITY. J.D. Sweeney* and G.E. Miller, Canadian Forestry Service, Pacific Forestry Centre, 506 West Burnside Road, Victoria, B.C., V8Z 1M5

The Douglas-fir cone moth, Barbara colfaxiana, is the most damaging pest of Douglas-fir seed in British Columbia's forests. In order to develop an efficient method of estimating cone moth densities one must first determine the pest's spatial distribution. Samples were taken from three locations in the southern interior of British Columbia in 1983 and 1985. In each location, the cone moth eggs were counted on conelets collected from four aspects and three crown levels from each of 10-15 trees. In this paper we present data on the distribution of cone moth eggs within and among trees and calculate the optimum sample size for estimating egg densities.

PREDATION OF SOIL-DWELLING STAGES OF THE SPRUCE BUDMOTH, ZEIRAPHERA CANADENSIS (LEPIDOPTERA: OLETHREUTIDAE) DIFFERS IN NATURAL AND MANAGED STANDS. Dan T. Quiring and Brian Carter, Department of Forest Resources, University of New Brunswick, Fredericton, New Brunswick, Canada E3B 6C2.

In a study investigating why populations of the spruce budmoth are usually higher in managed than unmanaged stands in eastern Canada we tested the hypotheses that i) the greatest mortality occurs during the prepupal and pupal stages when individuals are exposed to soil predators, and ii) predation of prepupae and pupae is highest in unmanaged stands of white spruce due to a greater abundance of ants.

Comparisons between prepupal and pupal samples showed that >96% of prepupae died in a natural white spruce stand but <90% did in an adjacent white spruce seed orchard. Visual observations and collections of predators carrying moth prepupae determined that most mortality was caused by three species of ants. As predicted there were more and larger ant hills in the natural stand. The incidence of pupal predation was also higher in the natural stand (~96 and 88% in the natural and managed stand respectively). Reasons for and implications of the different levels of predation on Z. canadensis will be discussed.

COMPETING VEGETATION AND SOUTHWESTERN PINE TIP MOTH (RHYACIIONIA NEOMEXICANA DYAR) INFESTATION INFLUENCE THE GROWTH OF PONDEROSA PINE (PINUS PONDEROSA DOUGL. EX LAVIS). D.W. Long*, M.R. Wagner, J.P. McTague, School of Forestry, Northern Arizona University, Flagstaff, Arizona 86011.

Rhyacionia neomexicana is an important pest affecting seedlings and saplings of southwestern ponderosa pine. It destroys terminal and lateral shoots of trees up to 8 feet in height. Repeated attacks cause trees to produce crooks, forks, and bushy forms. Established trees are rarely killed, but seedlings are susceptible and can be heavily damaged.

Plots were established in 1983 and 1984 to study the effects that weeding and tip moth control has on the growth of pine seedlings. Tip moth control had no significant effect on diameter growth, but it had a positive effect on height growth. Three years after plot establishment, the average growth of trees in tip moth controlled plots was 69% greater than non-controlled plots. Weeding had a positive effect on both height and diameter growth. Weeded plots had 107% increase in height growth and 63% increase in diameter growth over plots not weeded. Combining weeding and tip moth control resulted in the highest increase in height and diameter growth (147% and 77% respectively).

DISTRIBUTION AND LIFE HISTORY OF PONDEROSA PINE SAWFLIES (DIPRIONIDAE) IN WESTERN U.S. AND CANADA (HYMENOPTERA: DIPRIONIDAE). C.S. Dunbar and M.R. Wagner, Department of Forestry, Box 4098, Northern Arizona University, Flagstaff Arizona, 86011.

There are six different species of Diprionidae which feed on ponderosa pine, Pinus ponderosa, in western U.S. and Canada. We report the known distribution of Diprionidae species on ponderosa pine based on the evaluation of historic collection records. The distribution of several of these species overlap. We also report, to the extent known, the general life history of these species.

OVIPOSITION BEHAVIOR OF NEODIPRION FULVICEPS (HYMENOPTERA:DIPRIONIDAE) ON PONDEROSA PINE. R.A. Tisdale* and M.R. Wagner, School of Forestry, Northern Arizona University, Flagstaff, Arizona 86011.

Oviposition behavior of Neodiprion fulviceps was investigated on ponderosa pine Pinus ponderosa, its only known host in Arizona. The behavioral sequence of oviposition is stereotypical, with a high probability of transition from one event to the next once the sequence is initiated. Calling behavior is elicited immediately after they are placed on foliage. A great amount of time is spent walking up and down needles antennating and palpating needles prior to the oviposition sequence. No differences in oviposition behavior were observed on water stressed and non-stressed trees, however, a preference for water stressed trees was shown.

PERFORMANCE OF NEODIPRION FULVICEPS (HYMENOPTERA: DIPRIONIDAE) ON PUTATIVELY RESISTANT AND SUSCEPTIBLE PONDEROSA PINE TREES. Zhao Yi Zhang*, Michael R. Wagner, School of Forestry, Northern Arizona University, Flagstaff, Arizona, 86011 USA.

Eight pairs of susceptible and resistant ponderosa pine Pinus ponderosa trees were chosen in Flagstaff Arizona for bioassay of putative genetic resistance to pine sawfly Neodiprion fulviceps (Hymenoptera:Diprionidae). A complete generation bioassay was conducted on caged and uncaged branches in the field. On caged branches, sawfly egg hatch rate was 94.6% on susceptible trees vs 81.9% on resistant trees; larvae survival rate was 19.8% on susceptible trees vs 11.9% on resistant trees. Total survival rate was 18.7% on susceptible trees vs 9.7% on resistant trees. On uncaged branches, sawfly egg hatch rate was 96.3% on susceptible trees vs 87.9% on resistant trees; larvae survival rate was 22.1% on susceptible trees vs 13.6% on resistant trees. Total survival rate was 21.3% on susceptible trees vs 11.9% on resistant trees. These results indicate that sawfly development was affected by the resistance characteristic of the host tree. This differential performance may be the result of genetic resistance.

APPLICATION OF GEOGRAPHIC INFORMATION SYSTEMS TO THE GYPSY MOTH. S.H. Gage* and B. Parks, Dept. of Entomology, Michigan State University, East Lansing, Michigan 48824.

A geographical analysis of the temporal and spatial dynamics of the gypsy moth (*Lymantria dispar*) based on pheromone trap catch and defoliation history is presented as a decision making model. Change in trap catch over a 3 year period in Michigan shows dramatic increases in population levels. The design of the trapping network is shown to be a major asset for interpretation of trap catch. The analysis includes relationships of gypsy moth with forest types, land use and human transportation systems.

EFFECTS OF SELECTED INSECT GROWTH REGULATORS ON THE EASTERN SPRUCE BUDWORM, *CHORISTONEURA FUMIFERANA* (LEPIDOPTERA : TORTRICIDAE).

H. Mulye* and R. Gordon, Department of Biology, Memorial University of Newfoundland, St. John's, Newfoundland, Canada A1B 3X9.

The effects of two juvenile hormone analogs, methoprene (isopropyl (2E,4E)-11-methoxy-3,7,11-trimethyl-2,4-dodecadienoate) and fenoxycarb (ethyl [2-(p-phenoxyphenoxy) ethyl] carbamate), were evaluated on last (sixth) instar larvae of *C. fumiferana*, reared on an artificial diet. Topical application of methoprene resulted in supernumerary molting, formation of larval-pupal intermediates, with incapacity of adults to eclose. Fenoxycarb, more toxic of the two juvenoids, lengthened the duration of the sixth instar and caused larval-pupal intermediates, without supernumerary molting.

Based on the use of dose-response curves obtained for these insect growth regulators, physiological effects upon the target pest are being monitored. Incorporation of insect growth regulators into forest pest control programs is advocated.

AVERMECTIN B_{1a} AND MILBEMYCIN D AS CONTACT TOXICANTS FOR THE GYPSY MOTH. D.C. Deecher*, J. Brezner and S.W. Tanenbaum, Department Forest Biology, SUNY Environ. College Forestry, Syracuse, New York, USA 13210.

The management of gypsy moth (Lepidoptera: Lymantriidae) populations require a control procedure that demonstrates minimal environmental perturbation. Chemicals used in these procedures should have high efficacy, short residuals, innocuous metabolites, quick knock down and minimum non-target toxicity. Two of the newer macrolactones, Avermectin and Milbemycin, may possess these properties. Experimental work is being carried out in testing the chemicals against all life stages of the gypsy moth. The LD₅₀'s have been determined for both chemicals. It has been reported that both chemicals have LD₅₀'s that range in the lower spectrum of modern insecticides. Further study in progress will determine LC₅₀'s and forest non-target organisms susceptibility to these chemicals.

DEPOSITION OF AERIALY APPLIED FENITROTHION IN THE LARVAL MICROHABITAT OF SPRUCE BUDWORM, *CHORISTONEURA FUMIFERANA* CLEMENS. (LEPIDOPTERA; TORTRICIDAE), IN BALSAM FIR, *ABIES BALSAMEA* (L.) MILL. P.C. Nigam, Canadian Forestry Service - Maritimes, Fredericton, N.B. Canada E3B 5P7.

Spruce budworm larval microhabitats are composed of silken structures produced by larvae, new needles of growing buds and sometimes year old needles of balsam fir, at the time of operational spraying of fenitrothion in New Brunswick. Dose transfer of fenitrothion to the larvae from the droplets deposited in microhabitats takes place through setal or cuticular contact with contaminated silk strands and needles or by feeding on the contaminated new foliage of the growing buds. The deposits of two fenitrothion formulations are quantified and characterized on the various components of larval microhabitats i.e., silk strands, new needles and old needles. Their significance is discussed in the dose transfer process and effectiveness of fenitrothion.

GYPSY MOTH ERADICATION PROGRAMS IN LANE CO. OREGON
Alan D. Mudge, Oregon State Department of Agriculture
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During the summer of 1984, over 19,000 male gypsy moths (*Lymantria dispar* L.) were detected in Lane Co. Oregon. The Oregon State Department of Agriculture took the lead role in implementing a large scale eradication program consisting of state and federal quarantines, aerial applications of *Bacillus thuringiensis* (Bt), mass-trapping in core areas and post-treatment delimitation surveys.

Aerial applications of Bt were completed during the spring of 1985, 1986 and 1987 over 225,000, 189,000 and 7,400 acres respectively. Post-treatment gypsy moth detections decreased to 1,278 (1985), 81 (1986) and 41 (1987).

Residual populations of the gypsy moth in Lane Co. consist of 26 detections representing three isolated pockets of infestation with an additional 15 detections at scattered sites. Proposed eradication activities for 1988 include a fourth aerial spray program using Bt over approximately 3,000 acres followed by a post-treatment delimitation survey.

MODELLING GROWTH IMPACT OF DEFOLIATED BALSAM FIR BY SPRUCE BUDWORM IN NEWFOUNDLAND. E.J. Dobesberger, Newfoundland Forestry Centre, Canadian Forestry Service, Box 6028, St. John's, Nfld. Canada A1C 5X8

Evaluation of tree response to pest injury is essential to the development of effective forest pest control management strategies. Forest management requires more precise information on the impact of major defoliators such as the spruce budworm, *Choristoneura fumiferana* (Clem.), on growth and yield of economically important tree crops such as balsam fir, *Abies balsamea* (L.) Mill., in Newfoundland.

Between 3-7 July 1984, the current year foliage was artificially removed by visual estimation from five randomly selected trees in each of ten, 10% defoliation categories ranging from 10% to 100%. A subsample of 2-3 trees per category was redefoliated at identical intensities during 1985. For both years, timing of defoliation coincided with emergence of naturally occurring fifth instar spruce budworm larval populations. Fifty defoliated and 30 non-defoliated trees were harvested on 28-30 October 1985. Stem analyses were conducted to determine and compare annual stemwood volume increments (cm³) of defoliated and non-defoliated trees.

Analysis of the previous five year's volume increment from non-defoliated trees to determine potential volume increment revealed a strong, linear relationship between current volume increment, Y_1 , and initial tree volume, X_1 : $Y_1 = 54.225 + 0.434X_1$, $R^2 = 0.84$. Comparison of potential volume increment with actual volume increment of defoliated trees revealed a delayed response after the first defoliation treatment. After the second defoliation treatment, volume increment growth, Y_2 , was strongly correlated to percentage defoliation, X_2 : $Y_2 = 100.513 - 12.946X_2 + 0.211X_2^2$, $R^2 = 0.85$. Twenty to 30% defoliation for two years resulted in over-compensatory volume increment growth. Some tree mortality also occurred at 100% defoliation.

THE SYNCHRONIZATION OF OUTBREAK CYCLES OF DOUGLAS-FIR
TUSSOCK MOTH IN NORTH AMERICA (LEPIDOPTERA: LYMANTRIIDAE).
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Burnside Road, Victoria, British Columbia, Canada, V8Z 1M5.

Comparison of historical outbreak patterns of Douglas-fir
tussock moth, *Orgyia pseudotsugata*, over western North
America revealed that collapse of the outbreaks occurred
in a wide-spread synchronous manner, particularly in
British Columbia, Washington, Oregon and northern Idaho.
Populations increase to outbreak and collapse repeatedly
on an apparent 9-year cycle. Evidence suggests that a
nucleopolyhedrosis virus is responsible for the cycling.

THE SAXAUL MOTH *PROCERATIA CAESARIELLA* ROG. (LEPIDOPTERA: PYRALIDAE), A SEED PEST OF *HALOXYLON* SPP., IN IRAN. E. Adeli, The University of Tehran, Faculty of Natural Resources, Karaj, Iran.

The saxaul moth is widely distributed in saxaul growing regions in Iran. The rate of injury, being dependent on the density of its population, reaches up to 95% of the seeds of *Haloxylon* spp. around Tehran. This insect overwinters as a pupa in its cocoon in the soil where it spends a 9 month diapause. The adults emerge when the seeds are well grown in October. Both males and females are attracted to light. The eggs are deposited in young branches and calyxes. Hatching takes place in about two weeks and the larvae complete their growth around the end of November. It has one generation per year. We have found two species of hymenopterous parasites of the pupal stage in Iran. Other natural enemies, like the bombyliid *Villa* sp., also attack the pupae.

THE SAXAUL SCALE *ACANTHOCOCCUS* SP. (HOMOPTERA: ERIOCOCCIDAE), THE MOST IMPORTANT PEST OF *HALOXYLON* SPP. IN IRAN. M. Abai, Plant Pests and Diseases Research Institute, P.O. Box 1454, Tehran 19395, Iran.

Afforestation by the new method of planting *Haloxylon* spp. in Iran aiming at the stabilization of sand dunes, land reclamation, soil preservation and watershed management, are very important in most parts of the country. The economic points of view and industrial benefits are quite obvious today. Over the last 20 years, 0.5 million hectares of sand dunes in Iran have been planted with various species of saxaul trees. At the present time a very injurious insect, *Acanthococcus* sp., is one of the most serious pests of *Haloxylon* in Iran. The damage of this pest was first reported from north-east of Iran. The insect spread quickly throughout all saxaul afforested lands. The saxaul scale overwinters as an egg. The eggs hatch early in the spring. Both males and females have been found in infested areas. Egg laying occurs from August to November. It has one generation per year. The saxaul scale is attacked by two parasites in Iran.

INVESTIGATION OF THE WHITE WAX SCALE *ERICERUS PELA CHAVANNES* (HOMOPTERA: COCCIDAE) IN GUANGXI: 1. PRESENT PRODUCTION SITUATION AND ITS DEVELOPMENT POTENTIAL. Cen Ming, Ji Hong-Xian and Zeng Wei-Ming, Laboratory of Biology, Academy of Sciences of Guangxi, The People's Republic of China.

The warm weather and abundant rainfall in Guangxi are quite suitable for the growth and production of white wax scale. There are many available host plants, e.g. *Ligustrum lucidum* Ait., etc. There was some white wax scale long ago in thirteen counties of the Liuzhou, Hechi and Guilin regions. But white wax production has not been developed for a long time. Thus far we had been only able to get 50-150 kg each year because the control of insect pests, especially the parasitic bee *Microterys* sp., etc., was unsolved. The white wax scale has one generation each year. Usually they overwinter as a fertilized mature female. There is also some egg overwintering (10.7%). Our survey and experiments suggest that the wax secreting and breeding of the insect have improved because we have solved the control of the pest insects. There is potential for development of white wax production in Guangxi.

THE BIOLOGICAL CONTROL OF THE BLACK PINE APHID, *CINARA CRONARTII* T. & P. IN SOUTHERN AFRICA. N.J. van Rensburg, Plant Protection Research Institute, Private bag X134, Pretoria, 0001, South Africa.

A biological control programme against the black pine aphid, *Cinara cronartii*, a native of North America and a severe pest of exotic pine plantations in southern Africa, is described. An aphidiid parasitoid, *Pauesia* sp., was introduced from the United States of America in 1983 and about 210 000 individuals were released in pine plantations in South Africa (Transvaal and Natal) and Swaziland. The parasitoid established within the first year following releases and within two years spread by itself throughout the sub-continent's pine growing areas infested with the black pine aphid.

Seasonal fluctuations in the aphid numbers and the rates of parasitism are discussed. Owing to a reduction in the density of the aphid population since 1981, probably in response to several relatively dry years, the ability of the parasitoid to regulate severe outbreaks of the black pine aphid during normal years remains untested.

STUDIES ON PHYSIOLOGY AND HOST-PARASITE INTERACTION OF CERTAIN CECIDOMYIID GALLS. U. Kant, Department of Botany, University of Rajasthan, Jaipur-302004, India.

Plant galls induced by cecidomyiids provide an interesting study because of their pathological significance and economic importance. To understand the phenomenon of abnormal growth, the gall tissues of *Mangifera indica* induced by *Amradiplosis brunneigallicola*, *Syzygium jambolanum* induced by unknown Itonididae, and *Prosopis cineraria* leaf rachide gall induced by *Lobopteromyia prosopidis* were selected for study. Histopathology, biochemistry and histochemistry of these insect induced galls have been studied. Development of cecidomyiids in association with gall has also been studied. Hypertrophy and hyperplasia of the cells play a major role in gall development. Gall tissues showed higher auxin and phenolic contents with lower IAA oxidase and polyphenol oxidase activity compared to normal tissues *in vitro*.

MECHANISM OF THE ABNORMAL LEAF ABSCISSION IN JAPANESE CYPRESS (*CHAMAECYPARIS OBTUSA*) CAUSED BY FENITROTHION AND ITS RELATED COMPOUNDS. K. Tabata, Kansai Branch Forestry & Forest Products Research Institute, Momoyama, Fushimi-ku, Kyoto 612 JAPAN.

In 1975 the abnormal leaf abscission in Japanese cypress was discovered in fenitrothion aerial spraying area and its surrounding for controlling of the Japanese pine sawyer, *Monochamus alternatus*. This serious damage was caused by fenitrothion and dimethylthiophosphate or dimethylphosphate type OP compounds. The abnormal leaf abscission was accompanied with remarkable endogenous ethylene evolution and accelerated by these compounds. However, such phenomena were inhibited by EPN and salithion. Also peroxidase activity in susceptible Japanese cypress was inhibited by fenitrothion and its related compounds *in vivo* and *in vitro*. It was proposed that the mechanism of the abnormal leaf abscission and following endogenous ethylene evolution was as follows: the peroxidase, which is concerned with ethylene synthesis in susceptible Japanese cypress was activated by fenitrothion and its related compounds and the increase of endogenous ethylene evolution was induced, as the results, the abnormal leaf abscission was occurred.

EUROPEAN FOREST DECLINE, METALS AND INSECTS
 Pekka Nuorteva, Department of Environmental Conservation, SF-00710 Helsinki, Finland
 Toxic metals and insect pests play important roles in the final stages of the air pollution released multistress disease killing forest trees in Europe. It exists, however very little evidence about the metal circulation in forest insects. Our studies show that food chain bioaccumulation of metals is of rare occurrence in Finnish forests. Some other, still unknown principles regulate the circulation and accumulation. Adult sphingid moths, for example, bear in their bodies lower levels of Al, Fe and Cd than it exists in their food plants during larval stage. Zn, on the contrary, is accumulated into them - possibly in order to eliminate the more toxic metals. Small-sized species of pine feeding moths seem to have higher metal contents than the big-sized ones. Considerable high Cd accumulation occurs in the cambium of conifers and is transferred to cambium feeding bark beetles (not to xylophagous) and to honeydew feeding *Formica*-ants. They have higher Cd contents than sarcosaprophagous insects. Hypothetically Cd accumulation in ants may decline their effectivity as forest pest predators.

EFFECTS OF BRANCH ARCHITECTURE ON JUNIPER TWIG PRUNER, *STYLOXUS BICOLOR* (COLEOPTERA: CERAMBYCIDAE) SUCCESS.
 J. K. Itami, Department of Biology, Northern Arizona University, Flagstaff, Arizona, USA 86011

The probability of successful completion of the 3 year life cycle of the juniper twig pruner, *Styloxus bicolor*, was a function primarily of the branch architecture of its host, *Juniperus monosperma*. The oviposition site chosen by the adult female determined the branch where the larvae would complete development. In each of three years, the larvae moved down the branch forming feeding galleries at points determined by branch architecture. Branch architecture changed with tree age. Branch size had a large influence on whether larvae would survive or die from a variety of mortality factors. Beetle survival was much higher in small diameter branches because host related larval mortality was more frequent in large diameter branches.

The larval branch pruning behavior is a form of resource manipulation enhancing the quality of larval food resources. Pruned branches were significantly higher in xylem nitrogen and mineral content compared to unpruned branches.

FOREST COLEOPTERA IN PORTUGAL - AN ECOLOGICAL APPROACH TOWARDS OUTBREAK FORECASTING. M.R. Paiva*, J. Araujo, New University of Lisbon, FCT/DCEA, 2825 Monte de Caparica and University of Evora, Department of Biology, 7001 Evora, Portugal.

Three types of forest ecosystems are analyzed: pine canopies, mediterranean *Quercus* associations and eucalyptus monocultures. Recurrent problems caused by bark beetles and wood borers are related to either stress factors and/or poorly conducted cultural practices. Outbreaks of the primary scolytid *Tomicus piniperda* L. in northern Portugal occur in the vicinity of fire weakened stands and colonization by other species soon follows. In southern Portugal *Orthotomicus erosus* (Woll.) can become an agent of pine destruction after inadequately controlled ground fires. Increased stress has been placed on *Q. suber* and *Q. rotundifolia* in recent decades as a result of excessive cork harvesting and elimination of the natural vegetation. This causes outbreaks of several buprestids, curculionids and cerambycids. Eucalyptus plantations are menaced by the cerambycid *Phoracantha semipunctata* Fab. and pest populations are found where trees have been planted in inappropriate soil types or climatic regions. The need for an integrated approach to reduce the impact of forest coleoptera will be discussed.

ESTIMATING WESTERN PINE BEETLE-CAUSED TREE MORTALITY FROM SEQUENTIAL AERIAL PHOTOGRAPHY. K.Q. Lindahl*, R.J. Brand, and D.L. Wood, Group in Biostatistics, School of Public Health, University of California at Berkeley, Berkeley, California, U.S.A. 94720.

Ponderosa pine mortality caused by the Western Pine Beetle, *Dendroctonus brevicornis*, on a 127,000 ha. study area was monitored from 1970 to 1973 using sequential aerial photography and subsequent ground-checking. WPB-caused mortality was estimated in six 130 ha. evaluation zones. Four statistical estimators were compared directly and in terms of their estimated variances. Ratio, jackknife, and regression estimators that utilized ancillary information from the aerial photographs were superior to a mean expansion estimator that did not utilize the ancillary information. Computer simulations were used to compare the four estimators at varying sampling intensities.

ATTRACTION AND AGGREGATION OF DACNE (COLEOPTERA: EROTYLIDAE) TO THE SHIITAKE MUSHROOM (*LENTINUS EDODES*). E.Ohya*, R.W.Howard**, T.Ikeda, T.Nakashima, S.Sakai, Forestry and Forest Products Research Institute, P.O.Box 16, Tsukuba Norin Kenkyu Danchi-nai, Ibaraki, Japan 305. **U.S. Grain Marketing Research Laboratory, 1515 College Avenue, Manhattan, Kansas 66502.

Dacne japonica and *D. picta* are the prevailing pests of the shiitake mushroom (*Lentinus edodes*) in Japan. Adults of *D. picta* survive for nearly 130 days under proper condition eating the mushrooms and laying approximately one thousand eggs on them. Larvae devour mushrooms and turn into pupae in them. It takes about 40 days for them to complete the life cycle.

Both species are attracted to the mushrooms by the odor. *D. picta* are frequently found to be aggregated on or beneath them, while *D. japonica* usually in pair. The stimulatory organs in Vertex-Pronotal and Elytra-Abdominal fashion may play an important role in those behaviors.

SELECTION OF RESISTANT TREES AGAINST PINE-WOOD NEMATODE. K.Kanamitsu*, School of Agriculture, Nagoya University, Chikusa-ku, Nagoya, 464 Japan.

Japanese pines, *Pinus densiflora* and *Pinus thumbergii*, have long been suffering from a serious disease caused by the combination of the pine-wood nematode (*Bursaphelenchus xylophilus*) and a cerambycid beetle (*Monochamus alternatus*). In many heavily damaged pine plantations, however, there remain some small number of trees that have survived from this disease. At a supposition that these surviving trees might have some degree of resistance, artificial inoculation of natural nematodes was made upon them. This experiment was repeated for three successive years over hundreds of candidate trees, and finally a small number of trees were selected to be considerably resistant to this disease. From these resistant mother trees, terminal shoots were cut and grafted in the nursery. The final test of nematode inoculation upon these grafted young trees showed almost the same resistance.

MASS TRAPPING OF TRYPODENDRON LINEATUM OL. (COLEOPTERA : SCOLYTIDAE): EFFECT ON INFESTATION OF CUT TIMBER LEFT IN THE FOREST. E. König, Forstl. Versuchs- und Forschungsanstalt Baden-Württemberg D-7800 Freiburg/Br., Federal Republic of Germany.

Field experiments in the south-west German foothills of the Alps were carried out 1985 through 1987 in forested blocks 6 to 30 hectares in size, and entirely isolated from one another by surrounding agricultural crops. In these blocks, logs of Norway spruce were cut each year in December/January at the rate of 2.2 m³/hectare and left in the woods. A survey at mid-July determined the attack on these logs by T. lineatum. In two of the blocks, mass trapping of T. lineatum was performed using Theyson flight barriers baited with LINOPRAX (R) at the rate of 5 traps per hectare. The third block served as a control.

In the mass trapping areas, the number of beetles caught was reduced by about 50 % from year to year. This resulted in a remarkable reduction of beetle infestation of the cut logs: In 1985 the beetle attacked 27 % and 28 % of the logs, in 1986 only 6 % and 15 %, and in 1987 the attacks were limited to 2 % while the beetle attacks in the control area increased from 7 % (1985) and 6 % (1986) to more than 13 % in 1987.

DISPERSAL CHARACTERISTICS OF TRYPODENDRON LINEATUM (OLIV.) (COLEOPTERA: SCOLYTIDAE) WITHIN A VALLEY. S.M. Salom* and J.A. McLean. Faculty of Forestry, University of British Columbia, Vancouver, B.C. V6T 1W5.

A mark-recapture study examined Trypodendron lineatum spring flight dispersal in a coastal forested valley in British Columbia. Pheromone-baited traps were placed throughout the valley and catches of marked beetles were related to weather, topography, vegetative cover, and source of attractants.

A total of 43,000 marked beetles were released in 5 experiments. Beetles exhibited upwind flight response to traps 25 m away in the forest when wind direction was significantly directed. Beetles were captured at distances as far as 1.9 km up-valley and 1.3 km down-valley. Most beetles were captured within 2 hours of release at distances up to 50 m. From 350 - 700 m, as many beetles were caught during the day of release as in the following days. At distances greater than 1 km, almost all beetles took longer than 1 day to be captured.

ACCIDENTAL DISPERSAL AND COLONIZATION OF FOREST BEETLES (COLEOPTERA: SCOLYTIDAE). A.C. Nilssen, Zoology Department, Tromsø Museum, N-9000 Tromsø, Norway.

Evidence of long-distance aerial dispersal of spruce bark beetles (Scolytidae) is demonstrated with the following three methods:

1. By finds of bark beetles in gut contents of fish from mountain lakes far away from the nearest host trees.
2. By a field experiment where trap logs of spruce (Picea abies (L.) Karst.) were placed along a road north of and beyond the spruce forest in northern Finland.
3. By detecting the presence of host specific beetles in plantations of spruce in an otherwise spruceless part of northern Norway.

Aerial dispersal of 100-300 km is not uncommon, mostly by means of warm winds under certain meteorological conditions. Some species seem to be better colonizers than others.

TOLERANCE TO TERMITES AMONG COLD TOLERANT EUCALYPTS IN SOUTHERN AFRICA. M.J.P. Shaw* and C.R.E. Clarke, Sappi Forests Research, P O Box 75, Pietermaritzburg 3200, South Africa

The termite, Macrotermes natalensis is a serious pest of new eucalypt plantations in Southern Africa. A Eucalyptus species and provenance trial with 121 entries, planted in February, 1986, was severely attacked from October 1986 through to June 1987. There were significant differences in mortality among different Eucalyptus species, even "resistant" species are attacked when planted as monocultures. Trees are susceptible until the canopy closes 18-24 months after planting. At present the only practicable treatment seems to be soil insecticides at planting. The persistent insecticides dieldrin, aldrin and DDT have been banned in most countries, and chlordane could also be withdrawn where it has not already been prohibited. Controlled-release granular formulations (CRG) of non-persistent active ingredients have been tested as one way to circumvent this problem of residue persistency.

while E. nitens, E. fraxinoides and E. regnans were the most susceptible.

TRIALS WITH CONTROLLED-RELEASE INSECTICIDES GRANULES FOR TERMITE CONTROL IN FORESTRY PLANTATIONS. P.R. Atkinson, Institute for Commercial Forestry Research, University of Natal, South Africa.

Fungus-growing termites (Macrotermitinae) constitute a serious problem throughout Africa in the establishment of Eucalyptus and wattle on previously unafforested land. Although there is considerable variation in susceptibility among different Eucalyptus species, even "resistant" species are attacked when planted as monocultures. Trees are susceptible until the canopy closes 18-24 months after planting. At present the only practicable treatment seems to be soil insecticides at planting. The persistent insecticides dieldrin, aldrin and DDT have been banned in most countries, and chlordane could also be withdrawn where it has not already been prohibited. Controlled-release granular formulations (CRG) of non-persistent active ingredients have been tested as one way to circumvent this problem of residue persistency.

In five replicated field trials, mean mortality of untreated trees two years after planting was 54%, whilst chlordane at 0.6 g active ingredient per tree gave 5%, and the best CRG treatment, namely 2-3 year release-rate carbosulfan at 1.0 g a.i./tree, gave 13%. Eight subsequent trials have compared carbosulfan CRG with other soil insecticides; compared different release rates and granules sizes; and tested the substitution of cheaper carbofuran for carbosulfan.

COMPARATIVE STUDY ON POPULATION DYNAMICS OF DENDROLIMUS SUPERANS BUTLER (LEPIDOPTERA: LASIOTRAMPIDAE) AND PARASITE POPULATION AMONG DIFFERENT FOREST TYPES IN HOKKAIDO, JAPAN. K. Fukuyama, Forest Protection Division, Forestry and Forest Products Research Institute, Ibaraki, 305 Japan.

The study on population dynamics of hibernated larvae of Dendrolimus superans, a defoliator of coniferous tree in relation to its parasites, was carried out in four types of forest (natural coniferous forest and wind break larch forest, man-made todo-fir forest, and snow break spruce forest) in Hokkaido, northernmost part of Japan from 1977 to 1984.

The population densities in the natural coniferous forest were constant annually. On the other hand, annual fluctuation was great in the man-made forest of Abies sachalinensis. The species diversity of parasitic insects in the natural coniferous forest was higher than that in the man-made forests. There was a positive correlation between larval population and parasitic rate in the natural coniferous forest but negative correlation in the man-made forests. Parasitic insects were supposed not to play a critical role to regulate the population densities of D. superans in the man-made forests.

INTERACTIONS OF *FORMICA OBSCURIPES* FOREL, WITH "KEY" INSECT PESTS OF PINES. N.J. Campbell*, and G.A. Simmons, Department of Entomology, Michigan State University, East Lansing, MI. 48824.

The interactions of *Formica obscuripes* with several "key" insect pests of pines was examined in the upper-lower peninsula of Michigan during the summer of 1987. Ant predation was recorded on jack pine budworm (*Choristoneura pinus*), redheaded pine sawfly (*Neodiprion lecontei*), and gypsy moth (*Lymantria dispar*) in the presence and absence of aphids (*Cinara* sp.). *F. obscuripes* removed all of the "pest" larvae in each of the respective experiment replications at two different ant colonies, while controls excluding ant predation showed a 1-10% loss from other causes. When aphids were present, the ants responded to all prey at a much faster rate.

POTENTIAL ENDOPARASITOIDS FOR BIOCONTROL OF THE INDIAN SANDALWOOD DEFOLIATOR, *SYNTOMIS PASSALIS* (F.) (LEPIDOPTERA : ARCTIIDAE). Venkatesha and K. Gopinath*, Department of Studies in Zoology, University of Mysore, Manasagangotri, Mysore - 570 006, India.

Of the 5 arctiid defoliators of the Indian Sandalwood, *Santalum album* L., *Syntomis passalis* is the most important pest in South India having a peak period of incidence during August to November. Field surveys did not reveal any microbial disease and effective check of the pest against outbreak proportions is exerted by *Palexorista* sp. and *Blepharella* sp. (Tachinidae) and *Apanteles* nr. *nepitae*, *A. obliquae* var. *niger* and *Meteorus* sp. (Braconidae). Interestingly, *Palexorista* sp. has its suppressive influence at the start of the upswing of pest population aided by the less frequent *Blepharella* sp. *A. nr. nepitae* took over from the tachinids to signal the end of the peak infestation period aided by the less frequent *A. obliquae* var. *niger*. The other braconid, *Meteorus* sp. occurred only rarely to augment the suppressive influence. All the endoparasitoids are new records and the host-parasitoid complex will be discussed.

SYSTEMATIC POSITION, BIOLOGY, AND ECOLOGY OF SCOLYTOMOTES HOKEYI N. SP., N. GEN. N. TRIBE (ACARI: DOLICHOCYBOIDEA) A NEW PARASITOID OF BARK BEETLES (SCOLYTIDAE). M.J. Kaliszewski*, E.A. Cross, Department of Biology, The University of Alabama, Tuscaloosa, AL 35486, USA, J.C. Moser, U.S. Forest Service, Southern Forest Experimental Station, 2500 Shreveport Highway, Pineville, LA 71360, USA, T.W. Phillips, The University of Florida, Gainesville, FL 32611, USA.

Systematic position, biology, and ecology of *Scolytomotes hockeyi* n. sp., n. gen., n. tribe (Acari: Dolichocyboidea) a new parasitoid of bark beetles (Scolytidae) are analyzed and discussed. This study is based on specimens found in Florida and Australia.

ICHNEUMONIDAE (HYMENOPTERA) AND THEIR ROLE IN THE MAIN FOREST COMMUNITIES IN THE SURROUNDINGS OF KRYNICA (BESKID SADECKI, KARPATY MTS.). Tadeusz Kaźmierczak, Academy of Agriculture in Kraków, Department of Forest Entomology 31-425 Kraków, 29 Listopada Avenue 46, Poland.

In the years 1981-1987 entomological investigations were made of the main forest communities of the Karpaty Mountains around Krynica. Trophic relationships were established between 32 species of pest insects and 56 of their parasitoids. A total of 397 species of Ichneumonidae were found. The *Dentarto glandulosae* - *Fagetum* forest community was the richest and contained 1984 spp. of Ichneumonids. Ichneumonids are estimated to reduce forest pest populations by 58%. Ten zoogeographical groups were distinguished among which European elements (98 species) were most numerous.

PARASITOID COMPLEX OF TERMINAL WEEVILS AFFECTING LODGEPOLE PINE IN BRITISH COLUMBIA, CANADA. E. Kovacs* and J.A. McLean. Faculty of Forestry, University of British Columbia, 2357 Main Mall, Vancouver, B.C. Canada V6T 1W5

Infested lodgepole pine leaders were collected throughout British Columbia and reared in the laboratory in 1986 and 1987. Three weevil species were reared: *Pissodes terminalis* Hopping, *Magdalis gentilis* LeC. and *Cylindrocopturus* sp. The main emergence periods for *M. gentilis* and *P. terminalis* were late May and late June, respectively.

Parasitoids reared from the infested leaders had representatives from 8 genera in 5 families of HYMENOPTERA. Field observations showed that parasitoids feed on pollen of flowering weeds. Cultivation of lupin, *Lupinus* sp., near or on lodgepole pine plantations could enhance natural parasitoid populations.

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COLONIZATION DYNAMICS OF *TOMICUS PINIPERDA* L. AND *IPS SEXDENTATUS* BOERN (COLEOPTERA : SCOLYTIDAE) ON SCOTS PINE. L. Bouhot, F. Lieutier* and D. Debouzie. INRA, Zool. Forest., Ardon, 45160 Olivet, France, and Laboratoire de Biométrie, Univ. Lyon I, 69622 Villeurbanne Cedex, France.

In 1986, the spatial and temporal distribution of *T. piniperda* and *I. sexdentatus* have been studied on 6 Scots pines felled in the Orléans Forest (France). The data concerning *T. piniperda* were completed in 1987 with the setting of 16 additional trap-trees. For *I. sexdentatus*, during the colonization, there were shiftings of attacks from a trunk to another, from the base to the top of the trees and from their upper to their lower face. These spreadings of infestations can be at least partly explained by the progressive saturation with insects of the most suitable places for the establishment of this beetle. For *T. piniperda*, no real shifting of attacks from a trunk to another has been observed. Moreover, it is only in 1987 that *T. piniperda* attacks spread around the bole and very slightly spread up (high attack densities). This shifting of infestations around the bole seems furthermore to express the thermic preferences of *T. piniperda* rather than saturation phenomena. The crossings between the trunks of the felled trees were shown to have an effect for *I. sexdentatus* (peaks of attack densities) and none for *T. piniperda*. The behavioural differences observed in the colonization dynamics of these two bark beetles could be explained by the existence of aggregation pheromones for *I. sexdentatus* and their possible non-existence for *T. piniperda*. In order to work out sampling procedures, these results should be taken into account.

#128

BIOASSAY CHAMBER AND PROCEDURE FOR THE STUDY OF OVIPOSITION BY *MONOCHAMUS SCUTELLATUS* (SAY) (COLEOPTERA: CERAMBYCIDAE) AND OTHER WOOD-BORING BEETLES. J.V.R. Chénier* and B.J.R. Philogène, Department of Biology, University of Ottawa, Ottawa, Ontario, Canada K1N 6N5.

As part of a study of host selection by *M. scutellatus* and other conifer-feeding beetles, a bioassay chamber and test procedure were developed to determine which factors are involved in the selection of substrates for oviposition. The chamber consisted of a translucent vinyl cylinder placed upright on a screen floor, above a hollow space in the chamber bottom. Holes were cut in the screen to provide access to test substrates. Substrates in most tests consisted of plugs of tree bark placed on 1% agar in Stender preparation dishes. For every replicate of an experiment, a female was placed on the screen in the chamber and left for 24 hr. Response consisted of the number of eggs laid on each of the test substrates. Data were analysed non-parametrically.

An experiment in which plugs of bark of four conifer species were offered showed that *M. scutellatus* laid more eggs in white spruce and red pine, followed by white pine and balsam fir. A series of experiments showed that volatiles of host and non-host bark had no effect on the selection of oviposition substrates. Beetles oviposited equally in the phloem or in the outer bark of red pine and white spruce. Texture of red pine bark did not affect oviposition. Evidence indicates that contact chemical cues play a prime role in the evaluation of oviposition substrates for *M. scutellatus*.

#129

DEFENCE OF NORWAY SPRUCE TREES AGAINST THE EURASIAN SPRUCE BARK BEETLE, *IPS TYPOGRAPHUS*, AND ITS SYMBIOTIC FUNGI.

E. Christiansen, Norwegian Forest Research Institute, P.O.Box 61, N-1432 Ås-NLH, Norway.

Ips typographus transmits spores of several microorganisms to its host trees. At least one fungal species, *Ophiostoma polonicum*, is capable of killing healthy trees when mass-inoculated under the bark. Norway spruce, like several other conifers, possesses a dual defence system to counteract the beetle/fungus attack: 1. preformed resin in ducts of the bark and wood to stop boring beetles, and 2. induced resinosis in reaction zones which form around points of fungal infections. The secondary resinosis depends on effective energy (sugar) translocation to the sites of infection.

Ips typographus mainly attacks at about bud-burst, a time of high energy demands for growth in the trees. Several environmental factors can be assumed to reduce carbohydrate availability for defence, and thus enhance beetle/fungal success.

#130

USE OF PRESCRIBED BURNING TO CONTROL THE WHITE PINE CONE BEETLE, *CONOPHOTHORUS CONIPERDA* (SCHWARZ) (COLEOPTERA: SCOLYTIDAE) IN AN EASTERN WHITE PINE SEED ORCHARD. G. L. DeBarr* and L. R. Barber, USDA, Forest Service, Southeastern Forest Experiment Station, Carlton Street, Athens, Georgia, USA 30602.

Losses of genetically improved seed approach 100% without the use of insecticides to control *C. coniperda* in seed orchards of eastern white pine, *Pinus strobus* L. A study was conducted in a seed orchard located in Cherokee Co., North Carolina to evaluate the potential of using prescribed burning instead of insecticidal control. Preburn and postburn samples of artificially placed cones and naturally occurring cones were used to estimate beetle densities and mortality. No live beetles were found in samples of naturally occurring cones taken after burning. Attacks on trees where burning had occurred were reduced by 80 percent. These attacks were delayed and were apparently due to reinfestation from unburned areas of the orchard. Results of this study suggest that the use of fire offers a practical, effective and economical alternative to insecticides, for control of *C. coniperda* in eastern white pine seed orchards.

#131

SOME ROLES OF ASSOCIATED FUNGI IN THE LIFE HISTORY OF THE BARK BEETLE, *IPS PARACONFUSUS* (COLEOPTERA: SCOLYTIDAE). J.W. Fox* and D.L. Wood, Department of Entomological Sciences, University of California, Berkeley, CA 94720.

Techniques were developed to rear *I. paraconfusus* using intact pine phloem in "feeding tubes" so that we could use x-ray photography to record the life history parameters of survival, size, time of development per stage and the amount of food consumed. Fungi in association with *I. paraconfusus* and other bark beetles were isolated and cultured. These fungi were introduced into the feeding tubes to observe their effects on the beetles' development. Axenic, untreated or axenically reared with selected fungi adult beetles were introduced onto pine bolts in controlled vessels to ascertain the fungi's effects on beetle colony development. The growth pattern and rate of associated and non-associated fungi on pine bolts were compared singly or in competition.

#132

HOST COLONIZATION BEHAVIOR OF THE RED TURPENTINE BEETLE *DENDROCTONUS VALENS*. K.R. Hobson*, I. Kubo, D.L. Wood, Department of Entomological Sciences, University of California-Berkeley, Berkeley, CA 94720, USA.

D. valens is attracted to volatiles of ponderosa pine resin. Fractionation of resin with chromatographic techniques and field testing of beetle in-flight behavior shows attraction to low boiling point compounds. Initial tests of interaction of *D. valens* and congener *D. brevicomis* do not show enhanced attraction of *D. brevicomis* to trees experimentally infested with *D. valens*. Natural history studies of *D. valens* document the timing of emergence, dispersal, attack, and brood development.

#133

STUDIES ON CECIDOMYIID-INDUCED GALLS ON *PROSOPIS CINERARIA*, AN ECONOMICALLY IMPORTANT PLANT. U. Kant* and Vidya Ramani, Department of Botany, University of Rajasthan, Jaipur 302 004, India.

Lobopteromyia prosopidis Mani (Cecidomyiidae) causes galls on the rachis of *Prosopis cineraria* L. Druce, an important plant for the economy of the arid and semi-arid zones of India. Various stages of cecidozoa and gall development have been studied. Cross sections of young and mature galls revealed larval cavities in the cortex, secondary vascular region and pith. Gall cavities open to the outside by a circular ostiole. Hypertrophy and hyperplasia of cells plays a major role in the gall development. Compact nature of parenchymatous cells of the cortex and lack of intercellular spaces is a consequence of the cecidozoan attack. In older galls tannin containing cells are formed in the cortical region, possibly a resistance factor for cecidogenetic action. An attempt is being made to culture the cecidozoan *in vitro*.

#134

SCOLYTIDAE AND THEIR HOST TREES IN CENTRAL JAPAN. H. Kinuura and K. Kanamitsu*, School of Agriculture, Nagoya University, Nagoya, 464, Japan.

About 30 species of Scolytidae were recorded from 40 species of host trees in recent two-year study in central Japan. Beetles of the genus *Scolytus* had a very limited range of the host tree, while the genus *Xylosandrus* were obtained from the widest range of host. *Xylosandrus germanus* was found in more than 30 different species of trees including many conifers. *Tomicus piniperda* and *Cryphalus fulvus* were only found in trees of the genus *Pinus*. The trees of *Cryptomeria japonica* and *Chamaecyparis obtusa*, which are the most important tree species in Japanese forestry, were mainly attacked by three species of the genus *Phloeosinus*. *Parabenzoin trilobum* was the tree in the surveyed area that hosted most frequently many different species of Japanese Scolytidae. The past records of scolytid occurrence in Japan by other workers were added, and the whole situation in central Japan was summarized on the Scolytidae and their hosts.

#135

PREDICTION PARAMETERS FOR INFESTATIONS IN SARDINIAN CORK-OAK FORESTS. P. Luciano, R. Prota*, Istituto di Entomologia agraria, Università degli Studi di Sassari, Sardegna, Italia.

The results are reported of monitoring over 20 years the composition and consistency of lepidopterous fauna in Sardinian forests of *Quercus suber* L. In particular, population density variations are described of *Tortrix viridana* L., *Malacosoma neustria* L. and *Lymantria dispar* L., which proved to be the most harmful insects. *T. viridana* showed temporary type fluctuations with 11-years latency intervals, while *M. Neustria* and *L. dispar* fluctuations were periodic. The gradation periodicity of *L. dispar* varied from 11 to 5-6 years in different parts of the island, probably due to different conditions of biological equilibrium conservation in each of the environments studied. The report concludes with a set of parameters characterizing each gradation phase of *L. dispar* (egg population density, eggs/egg-cluster, fertile egg percentage and parasitism rate), which enable its population trends to be predicted and prove useful in programming pest control operations.

#136

HEMLOCK WOOLLY ADELGID, *ADELGES TSUGAE* ANNAND, (HOMOPTERA: ADELGIDAE) MAY ALSO ATTACK SPRUCE. M.S. McClure, Valley Laboratory, Connecticut Agricultural Experiment Station, P.O. Box 248, Windsor, Connecticut, USA 06095.

Adelges tsugae is a serious pest of forest and ornamental *Tsuga canadensis* in the Northeastern United States. This adelgid also occurs on *T. heterophylla* in the Pacific Northwest where it sometimes injures cultivated trees, but where it is usually of little consequence in the forest. Until now *A. tsugae* was thought to have a simple, wingless parthenogenetic life cycle that was restricted to hemlock. However, my studies revealed a complex life cycle with several generations per year and new life stages including a winged stage that migrates to spruce. I conducted field and laboratory studies to determine if winged adelgids could colonize 12 native and exotic spruce species growing in Connecticut. I found winged adelgids had laid eggs on each spruce, but none of the nymphs that hatched survived. The species were *Picea abies*, *P. asperata*, *P. engelmannii*, *P. glauca*, *P. heterolepis*, *P. jezoensis*, *P. mariana*, *P. orientalis*, *P. polita*, *P. pungens*, *P. rubens* and *P. sitchensis*. I also found a few winged adelgids on hemlock following the migration period, but all died without producing offspring. Although *A. tsugae* is not a pest of the 12 spruces tested, the existence of winged adults is significant because they may eventually encounter a susceptible spruce species on which they can survive.

#137

MATING DISRUPTION SUPPRESSES *RHYACIONIA ZOZANA* IN YOUNG PINE PLANTATIONS. C.G. Niwa*, G.E. Daterman, C. Sartwell, and L.L. Sower, Pacific NW Research Station, USDA Forest Service, Corvallis, Oregon, USA 97331.

Hercon laminated-tape dispensers containing synthetic sex pheromone (a 95:5 mixture of E-9-dodecenyl acetate and E-9-dodecenol) of the ponderosa pine tip moth, *Rhyacionia zozana* (Kearfott), were manually applied on 57 ha of ponderosa pine plantations in southern Oregon. The nominal dosage was 13.5 g of AI/ha from 100 releasers per hectare spaced at 10 m. Male moth response to pheromone-baited traps and to virgin females in mating tables showed nearly total disruption of female sex pheromone communication with males. After the mating-disruption application, larval populations were reduced 83.2% in treated areas. The frequency of damaged terminal shoots was lower in pheromone-treated plantations than in check plots.

#138

MYCOFLORE ASSOCIEE AUX PUCERONS *CEYROBIUM LAPORTEI* REMAUDIERE ET *CINARA CEDRI* MIMÉUR DANS DES CEDRES DE L'ESPAGNE. A. Notario*, J.R. Baragaño et J. Tello, Departamento de Ingeniería Forestal, E.T.S.I. Montes, Madrid, España.

Des exemplaires de *Cedrus* spp. du centre de la Péninsule Ibérique sont attaqués souvent par les pucerons *Cedrobium laportei* Rem. et *Cinara cedri* Mim.

En général les dégâts causés par ces insectes sont liés à la présence de fumagine, qui peut produire la mort de l'arbre. A cause de cela, et avec la certitude de l'importance du complexe *Fumago vagans* le poster présente une étude sur la composition de la mycoflore de la phyllosphère des arbres en ces trois cas suivants:

1. Des cédres attaqués par *Cedrobium laportei* Rem.
2. Des cédres attaqués par *Cinara cedri* Mim.
3. Des cédres apparemment pas attaqués.

Tous les trois montrent visiblement la présence permanente des micro-mycètes *Epiccocum nigrum*, *E. purpurens*, *Alternaria tenuis*, *Cladosporium herbarum*, *Rhizopus* sp., *Aureobasidium* sp., *Botrytis cinerea*, *Migrospora* sp., *Fusarium oxysporum*, *F. moniliforme* et *F. roseum gibbosum*.

#139

VARIATION IN SPRUCE BUDWORM-CAUSED TREE MORTALITY OF BALSAM FIR AND BLACK SPRUCE BY TREE AND STAND PARAMETERS. A.G. Raske* and E.J. Dobesberger, Newfoundland Forestry Centre, Canadian Forestry Service, Box 6028, St. John's, Newfoundland, Canada A1C 5X8.

A total of 1680 semi-mature balsam fir, *Abies balsamea* (L.) Mill., and 748 semi-mature black spruce, *Picea mariana* (Mill.) B.S.P., trees were monitored annually for 14 years (1971 to 1984) for severity of spruce budworm, *Choristoneura fumiferana* (Clem.), defoliation and tree mortality. These trees occurred on 71 plots throughout the spruce budworm outbreak area in Newfoundland.

On a per tree basis mortality of balsam fir was least at 26% for trees with three years of severe defoliation, and was greater at 45% and 32% with two years and zero or one year severe defoliation respectively. Mortality increased with increased defoliation pressure to 34%, 46% and 49% with four, five and six to eight years of severe defoliation respectively.

Mortality of black spruce followed the same pattern as that for fir, although most spruce occurred on different plots than fir.

On a per tree basis tree mortality of spruce and fir combined varied with crown class from 20% of Dominant trees to 47% of the Suppressed trees. Tree mortality varied directly with tree density, and site quality. The better the site the greater the tree mortality.

#142

HOST FINDING AND COLONIZATION IN THE BARK BEETLE *TOMICUS PINIPERDA* (L.) (COLEOPTERA: SCOLYTIDAE). L.M. Schroeder, Swedish University of Agricultural Sciences, Division of Forest entomology, P.O. Box 7044, 750 07 Uppsala, Sweden.

The bark beetle *T. piniperda* breeds in Scots pine trees (*Pinus sylvestris* L.) that are windbroken, windthrown, or otherwise weakened. *T. piniperda* is strongly attracted by host monoterpenes and by combinations of monoterpenes and ethanol. These substances also induce attacks of *T. piniperda* on baited trees. Earlier studies have failed to demonstrate any aggregation pheromone in *T. piniperda*.

Somewhat higher numbers of beetles were caught on sticky traps on low vigor trees than on trees of higher vigor. Many more beetles were caught on trees attacked by *T. piniperda* and on trees with simulated bark beetle galleries (manually drilled holes) than on control trees with no or only a few attacks. Thus the strong attraction of beetles to attacked trees is attributed to the beetles responding to host volatiles released from the galleries.

#140

THINNING *PINUS PONDEROSA* FOR SILVICULTURAL CONTROL OF *DENDROCTONUS PONDEROSAE* (COLEOPTERA: SCOLYTIDAE). Charles Sartwell, Pacific Northwest Research Station, USDA, Forest Service, Corvallis, Oregon 97331, USA.

Outbreaks of mountain pine beetle in ponderosa pine forests of the northwestern United States occur mainly in even-aged stands about 50 to 80 years old. Severe tree killing is strongly correlated with high stand density. Beetle-killed trees characteristically have short crowns of foliage, and grew very slowly for more than 10 years prior to attack. This evidence indicates that low tree vigor from intense competition underlies the occurrence of beetle outbreaks, and suggests that management of stand density could be the key to outbreak prevention.

In 1967 a 100-hectare test of thinning to prevent severe tree killing by the beetle was begun near Baker, Oregon. Spacing treatments of 3.5, 4.5, 5.5, and 6.5 m covering 10 ha plots were replicated twice. The lightest thinning, which removed only suppressed and intermediate trees, failed to reduce damage. However, in the heavier thinnings, tree killing by the beetle has been 30 to 60 times less than in unthinned checks. Net growth has been strongly positive in the heavily thinned stands over the past 20 years, but has declined substantially in the unthinned checks.

#141

LARVAL PARASITIDS OF *CHORISTONEURA OCCIDENTALIS* AND *C. RETINIANA* (LEPIDOPTERA: TORTRICIDAE) AT EPIDEMIC AND ENDEMIC HOST DENSITIES. W.C. Schaupp, Jr.*, W.J.A. Volney/1 and W.E. Waters, Department of Entomological Sciences, University of California, Berkeley, CA, USA, 94720 and /1 Canadian Forestry Service, Northern Forestry Centre, Edmonton, Alberta, Canada, T6H 4N7.

Larval parasitoid species presence and relative abundance are presented from quantitatively defined collections of hosts reared in individual containers. Three years at extremely low host densities are contrasted with collections made during one year of the subsequent epidemic in southern Oregon. Similar comparison is made between moderate and epidemic density populations sampled over three years in New Mexico. *Campoplex* spp. and others (Hymenoptera: Ichneumonidae) appear to replace *Glypta fumiferanae* (Hymenoptera: Ichneumonidae) and *Apanteles fumiferanae* (Hymenoptera: Braconidae) at low host densities.

#143

THE ISOLATION AND IDENTIFICATION OF THE AGGREGATION PHEROMONE OF *IPS LECONTEI* SWAINE. S.J. Seybold*, J.E. Milstead, T. Ohtsuka, I. Kubo and D.L. Wood, Department of Entomological Sciences, University of California-Berkeley, Berkeley, CA 94720, USA.

In order to provide clues for the speciation of pine bark beetles in Group IX of the genus *Ips*, we have begun isolating aggregation attractants for the Arizona five-spined engraver, *Ips lecontei*. Volatile compounds associated with male insects excavating galleries in ponderosa pine logs were trapped on Porapak Q and this mixture was fractionated using HPLC. The fractions were tested for activity using a behavioral assay. Preliminary results indicate that the active fraction in the initial step of the sequential fractionation contains racemic ipsdienol and one optically pure isomer of ipsenol.

#144

ECOLOGY AND CONTROL OF THE SUGI BARK BORER, *SEMANOTUS JAPONICA*, CAUSING "HACHIKAMI" DAMAGE IN JAPANESE CEDAR STAND. E. Shibata. Nara Forest Experiment Station. Takatori, Nara 635-01 JAPAN.

Japanese cedar, *Cryptomeria japonica*, and Japanese cypress, *Chamaecyparis obtusa*, occupy the 7 million hectares of forest plantation in Japan. The expansion of planting these trees for last thirty years has been creating a serious problem due to wood-injuring insects in these commercial forests. The sugi bark borer is one of the most important wood-injuring insects in cedar and cypress stands. Though cedar is seldom killed by its attack, it is causative of the timber quality due to its feeding a cambium and subsequent invasion of wood rotting fungi. The damage of this insects widely distributed in Japan and heavily infested stands are found to a great extent. The intensive studies of this species, i.e., analysis of damaged forests in connection with the environmental factors, population dynamics in the cedar stands, and the evaluation of some control method have been done for constructing the IPM.

#145

REVIEW OF INSECTS FOUND IN CONES OF *ABIES ALBA* MILL. IN SOUTHERN POLAND. M. Skrzypczyńska, Department of Forest Entomology, Academy of Agriculture, 31-425 Kraków, Poland.

During 1976-1986, laboratory and field studies on the entomofauna of *A. alba* were conducted in southern Poland. A total of 45 insect species in the orders Heteroptera, Coleoptera, Raphidioptera, Hymenoptera, Lepidoptera and Diptera were found. Coenotic groups distinguished were: (a) conophagous insects – *Barbara herrichiana* Obr. (Lepidoptera: Tortricidae), *Dioryctria abietella* (Den. and Schiff.) (Lepidoptera: Phycitidae) and *Earomyia impossibile* Morge (Diptera: Lonchaeidae); (b) seminiphagous insects – *Megastigmus suspectus* Borr. (Hymenoptera: Torymidae) and *Resseliella piceae* Seitz. (Diptera: Cecidomyiidae); (c) parasitoids of the two insect groups mentioned above (17 species); saprophagous and coprophagous insects (8) and seasonal insects (15). Connections between parasitoids and their host were established: *Macrocentrus collaris* Spin. (Hymenoptera: Braconidae) – host *B. herrichiana*; *Mesopolobus pinus* Hussey (Hymenoptera: Pteromalidae) – host *M. suspectus*; *Platygaster* sp. aff. *manto* Walk. (Hymenoptera: Platygasteridae) – host *R. piceae*.

#146

DISTRIBUTION OF WHITE PINE CONE BEETLE POPULATIONS ON INDIVIDUAL TREES OF DIFFERENT SIZE AND AGE AND IN CONSECUTIVE GENERATIONS. G.R. Stairs, Department of Entomology, Ohio State University, Columbus, OH 43210 USA.

Conophthorus coniperda attacks 2nd year white pine cones and a tree may become infested as soon as it begins to produce a cone crop but trees producing large crops usually support the largest beetle populations. A few trees, however, appear to be consistently lightly infested and resistant to the beetle suggesting they are physiologically and/or genetically different from those that support consistently high populations. The ecological significance of these relationships in the survival of the two interacting species is discussed.

#147

FIRE HISTORY AND OUTBREAKS OF THE JACK PINE BUDWORM, *CHORISTONEURA PINUS PINUS* FREEMAN (LEPIDOPTERA: TORTRICIDAE), IN THE CANADIAN PRAIRIE PROVINCES. W. Jan A. Volney, Northern Forestry Centre, Canadian Forestry Service, 5320 - 122 Street, Edmonton, Alberta. T6H 3S5.

Over the past half-century, jack pine budworm outbreaks in the Canadian prairie provinces have occurred with a periodicity of approximately 10 years. The number of hectares burned annually shows the same periodicity; however, years in which the area burned peaks (fire years) are followed by outbreaks within 2 to 4 years. Fire years are associated with drought, which is thought to induce jack pine trees to flower abundantly, thereby increasing early instar jack pine budworm survival and the probability of outbreaks.

Jack pine stands are regenerated by fires, and naturally regenerated stands usually do not flower until they are 20 to 25 years old. Improved fire control procedures and the concomitant increasing age of jack pine forests account for the trend to greater outbreak size.

The association between fire history and outbreaks can be used in forecasting future outbreaks by up to 4 years.

#148

STUDIES ON THE BIOLOGY OF *TAENIOGONALOS VENATORIA* RIEK (HYMENOPTERA:TRIGONALYIDAE), A PRIMITIVE PARASITOID OF *EUCALYPTUS* DEFOLIATING PERGID SAWFLIES IN AUSTRALIA. P. Weinstein, Department of Entomology, Waite Agricultural Research Institute, University of Adelaide, South Australia.

Sawflies of the genus *Perga* (s.l.) are serious pests on *Eucalyptus* in southeastern Australia. In some seasons they appear to be regulated by trigonalid parasitoids. The primary focus of this study is the trigonalid *Taenigonalos venatoria*, which attacks *Perga* (s.l.) in the Adelaide region of South Australia. At present nothing is known of the life history of this parasitoid, nor of the host-parasitoid interactions of the Trigonalidae in general.

T. venatoria and other trigonalids are unique among the parasitic Hymenoptera because of their ovipositional strategies. Females of *T. venatoria* 'punch' eggs into the mesophyll of *Eucalyptus* leaves, and eclosion takes place only if the eggs are ingested by pergid larvae as they feed on the leaves. The trigonalids then develop as endoparasitoids, possibly as hyperparasitoids of ichneumonids or tachinids in the same host. Adult *T. venatoria* females emerge from the host cocoons and oviposit thousands of eggs parthenogenetically.

Present studies include determination of the cues utilised in host habitat and host location, and an assessment of the immune response of the host.

THE ROLE OF PHEROMONES AND ATTRACTANTS IN THE CONTROL OF STORED PRODUCT INSECT PESTS IN THE TROPICS. J.N. Ayertey (Nigeria)

No Abstract

MONITORING OF CIGARETTE BEETLE (*LASIODERMA SERRICORNE* F.) USING SYNTHETIC SERRICORNIN IN FIELD CONDITIONS. T. Chuman, K. Nakazawa, K. Okada, T. Imai and M. Kohno Central Research Institute, Japan Tobacco Inc., 6-2 Ume-gaoka, Midori-ku, Yokohama 227, Japan.

Serricornin is a sex pheromone produced from the female cigarette beetle which is a serious cosmopolitan pest of cured tobacco leaves, flour, spices and most of all dry food materials. The synthetic serricornin was tested to estimate the effectiveness for the attractant of the pest in field conditions. The results of the experiments in the test room indicated that the content ratio of (S,S,S)-natural serricornin and (S,S,R)-non-natural isomer in the synthetic serricornin was greatly affected to the trap efficiency due to the inhibitory effect of (S,S,R)-isomer to natural serricornin and the release control technique of the pheromone was also affected to the efficiency.

In a tobacco manufactory, tobacco warehouse and flour manufactory, the potential application of the synthetic serricornin as a lure of cigarette beetles for detecting and monitoring the infestations of this pest will be discussed.

PRACTICAL ASPECTS OF A CIGARETTE BEETLE PHEROMONE TRAPPING PROGRAM IN A CIGARETTE MANUFACTURING ENVIRONMENT. D. L. Faustini, Philip Morris, USA, P.O. Box 26583, Richmond, Virginia 23261, USA.

Sex attractant-baited sticky traps with Serrico disks consisting of (+/-)-serricornin synthesized by Fuji Flavor Co. were evaluated and compared with electric traps for effectiveness in capturing and monitoring the cigarette beetle, *Lasioderma serricorne* (F.) in a cigarette manufacturing environment. Results showed that sex pheromone traps were superior when compared with the conventional blacklight traps. Pheromone traps reduced the number of man hours spent to identify searches for infestations and were advantageous in assessing sanitation and chemical control measures. Also discussed are inherent problems related to instituting a large scale pheromone monitoring program in an industrial setting.

BEHAVIOURAL RESPONSE OF THE RICE WEEVIL, *SITOPHILUS ORYZAE* (L.) TO MALE AND FEMALE PRODUCED CHEMICALS. Vu Quoc Trung*, Karan Singh and S.K. Majumder, Infestation Control and Protectants Discipline, Central Food Technological Research Institute, Mysore - 570 013, India.

Volatile chemicals extracted from unmated male and female adults elicit aggregation and sex behaviour in *Sitophilus oryzae* (L.). The highest mating response was recorded with stimulus extracted from the thorax of the female. Aggregation was elicited by stimuli extracted from the thorax and abdomen of the male. When the responses of mixed populations of *S. oryzae* to stimuli were tested in a binary choice arena the maximum attraction was elicited by a female equivalent extraction obtained from the thorax and abdomen. The findings indicate that pheromone glands exist in the thorax and abdomen of the rice weevil.

USING INSECT TRAPS TO MONITOR STORED-GRAIN PESTS ON THE FARM. V.F. Wright*, T.W. Mize and J.R. Pedersen, Department of Entomology and Department of Grain Science and Industry, Kansas State University, Manhattan, Kansas, 66506 USA.

Two studies in Kansas located sources and kinds of insect infestation on farms. In 1986, 80 farms in 28 counties were monitored with 4 kinds of traps at wheat harvest (June) and in September. In 1987, five farms were monitored biweekly. Pheromone-baited wing traps, outside of grain bins, captured large numbers of IMM and LGB while food bait traps yielded the most other species in the greatest numbers. Corrugated cardboard bait traps containing pheromone for *Tribolium* spp. and an attractant bait for other beetles did not function well under farm conditions. Unbaited pitfall traps in binned grain caught more kinds and numbers of insects in warm weather than were found in grain trier samples. Before wheat harvest, traps showed moderate to high infestations at various locations on farms. Within one month, after harvest, pitfall traps indicated large numbers of insects in new grain. By September, insects trapped on farms had decreased and populations in bins had increased.

Wing traps indicated high populations of flying LGB in the spring of 1987, with a rapid drop over the summer. IMM populations were low in the spring, averaged 50 insects per wing trap through September, then decreased to 45 in November.

Insect numbers on farms were correlated with sanitation rating, pesticide usage and trap location.

ROUTE OF ENTRY OF STORED-PRODUCT MOTHS INTO FOOD DISTRIBUTION WAREHOUSES AS DETERMINED BY SEX PHEROMONE-BAITED TRAPS. K.W. Vick, USDA, ARS, Insect Attractants, Behavior and Basic Biology Research Laboratory, Gainesville, Florida, USA.

Attention has recently been drawn to populations of stored-product moths living in varied out of door habitats. The size and species composition of populations near food distribution warehouses will be described. The importance of these insects to infestation levels in nearby warehouses will be compared to infestations arising from insects living in the warehouses and from insects arriving at the warehouse in trucks and railcars.

FACTORS THAT MEDIATE THE RESPONSE OF *SITOTROGA CEREALELLA* AND *RHYZOPERTHA DOMINICA* TO PHEROMONES IN NATURAL ENVIRONMENTS. R. R. Cogburn, U.S. Department of Agriculture, Agricultural Research Service, Beaumont, TX, USA 77706.

A sex pheromone attractive to males and an aggregation pheromone attractive to both sexes have been identified for *S. cerealella* and *R. dominica*, respectively. The pheromones were used to determine the diurnal activity of the two species. *S. cerealella* was most active during darkness. Activity began to increase 4-6 hours after sunset, continued to increase until sunrise and declined thereafter. *R. dominica* was active at all hours but was more active during daylight. *S. cerealella* did not respond differently to various silhouettes or colors. *R. dominica* showed a statistically significant preference for rectangular silhouettes and dark colors but the preference was not strong enough in either case to suggest that traps for this species should be constructed according to silhouette or color. The spatial distribution of traps influenced captures of both species. Traps positioned 0.3 meters from the ground in outdoor locations or the floor inside buildings caught significantly more insects than traps positioned at 2 or 4 meters.

SOME NEW LURES, TRAPS AND SAMPLING TECHNIQUES FOR MONITORING STORED-PRODUCT INSECTS. Wendell E. Burkholder, ARS USDA Department of Entomology, University of Wisconsin, Madison, Wisconsin 53706 USA.

Several kinds of commercially available traps are being used to monitor the presence of insects in stored products. Improvements have been made in trap designs and new food and pheromone lures have been discovered. Although some pitfall traps are used without lures, evidence now indicates improvement in trap catch occurs with a combination of food and pheromone lures. Food lures may be freshly cracked grains, food oils or the synthetic essence of foods. The role of freshly cracked wheat in synergizing the response of maize weevils to the male-produced aggregation pheromone has been demonstrated. Farmers can make their own weevil lure by cracking grain and placing it in pitfall devices of simple designs. Pheromones of the important *Sitophilus* grain weevils as well as for many of the grain borers, grain beetles and other stored-product insects are now available. The traps reveal the presence of an infestation and the kinds of insects present. This is particularly useful following fumigations or other insecticide treatments. The new lures, traps and sampling procedures will be discussed. Future research is expected to relate the trap catch to predictions of insect infestation levels and damage.

PEROMONES AND FUNGAL VOLATILES: SEMIOCHEMICALS FOR STORED PRODUCT BEETLES. A.M. Pierce*, H.D. Pierce, Jr., J.H. Borden and A.C. Oehlschlager, Departments of Chemistry and Biological Sciences, Simon Fraser University, Burnaby, British Columbia, Canada V5A 1S6.

Stored product beetles were attracted to various alcohols and ketones in laboratory olfactometers. Many of the test compounds are known to be by-products of microbial growth. One of the most potent attractants, 1-octen-3-ol, was found to be produced as an aggregation pheromone by males and females of the cucujid grain beetles *Oryzaephilus surinamensis* (L.), *O. mercator* (Fauvel) and *Ahasverus advena* (Waltl). Some other species were repelled by moderate doses of 1-octen-3-ol.

THE SYNERGISM IN ERECTIN-LIKE ACTION OF BRUCHIDS. K. Tanaka, Y. Tanaka, H. Honda, and I. Yamamoto*, NODAI Research Institute, Tokyo University of Agriculture, 1-1-1 Sakuragaoka, Setagaya-ku, Tokyo 156, Japan.

The behaviour of the azuki bean weevil, *Callosobruchus chinensis*, is controlled by two pheromones, i.e. a sex attractant and a copulation release pheromone. The latter has no attractancy, but induces all the other mating responses, and was thus named erectin. It is a mixture of C26-C35 hydrocarbons and a dicarboxylic acid named callosobruchic acid, which acts synergistically, but any single component has almost no activity. In the yellow mealworm, *Tenebrio molitor*, the attraction of the male to the female is regulated by a sex attractant, 4-methyl-1-nonanol, but the copulation is caused by the synergistic action between the sex attractant and a lipid mixture. In both cases, the lipid components on the insect's body surface play an important role in inducing copulation after attraction.

EFFECT OF AGGREGATION PHEROMONES UPON ATTRACTION OF GRAIN AND FLOUR BEETLES TO SEVERAL TYPES OF TRAPS. H.D. Pierce, Jr.,* A. Javer, A.M. Pierce, J.H. Borden and A.C. Oehlschlager, Departments of Chemistry and Biological Sciences Simon Fraser University, Burnaby, B.C., Canada V5A 1S6.

The male-produced aggregation pheromones of *Cryptolestes ferrugineus*, *C. pusillus*, *Oryzaephilus mercator*, and *O. surinamensis* were found to significantly improve the efficacies of several types of traps to capture these cucujids maintained at low population density in wheat. The racemic aggregation pheromone of *Tribolium castaneum* and *T. confusum* had little effect on catches for trap types examined.

TRIBOLIUM SEMIOCHEMICALS AS INSECT HORMONE ANTAGONISTS: PHYSIOLOGICAL AND ECOLOGICAL IMPACTS ON STORED GRAIN INSECTS. Ralph W. Howard, U.S. Grain Marketing Research Laboratory, ARS, USDA, Manhattan, KS 66502 USA.

Prostaglandins are local cellular hormones involved in many physiological functions including oviposition behavior, egg hatching, and adult emergence and flight capabilities. Compounds that prevent the formation of prostaglandins (PSIs) are thus potential control agents for insect populations. I have found, identified, and quantified the first known animal derived PSIs. These compounds (2-hydroxy-4-methoxyacetophenone and 2-hydroxy-4-methoxy propiophenone) are found in the defensive secretion of 5 species of *Tribolium* and constitute up to 0.25% of their biomass. Three other species of *Tribolium* lack these inhibitors. I have also identified 7 other potent PSIs (including 2-aminoacetophenone, methylanthranilate, methyl salicylate, and salicylaldehyde) from 3 orders of insects. These hormone antagonists thus appear to be widespread and abundant insect components with possibly great ecological significance. The effects of some of these PSIs on the physiology and ecology of stored product insects will be discussed.

RECENT DEVELOPMENTS IN THE APPLICATION OF FOOD ATTRACTANTS AND PHEROMONES FOR THE DETECTION OF STORED-PRODUCT PESTS. D B Pinniger* and J Chambers. ADAS. Slough Laboratory, London Road, Slough, Berks SL3 7HJ. UK.

Early warning of pest presence is an increasingly important part of storage pest control strategy. Enhancement of physical traps by use of pheromone and food attractant lures shows great promise but the full potential of these developments will not be realised without an appreciation of the limitations of our knowledge of insect behaviour and the role of attractant chemicals. The paper discusses recent advances in the light of the need for development of practical detection strategies.

THE USE OF SEX PHEROMONES TO CAPTURE MALE GRASS MOTHS (LEPIDOPTERA: PYRALIDAE) IN CZECHOSLOVAKIA. F. Šifner, Czechoslovak Academy of Agriculture, Prague, Těšnov 65, ČSSR.

A mixture of the Z9,E12-14:Ac and Z9,E12-14:OH sexual pheromones at 9:1 ratio, included directly in the glue is used for the control of the complex of phycitid moths, *Ephesia elutella* (Hbn.), *E. cautella* (Wlk.), *E. kuehniella* Zell. and *Plodia interpunctella* (Hbn.). The glue is applied onto both sides of paper strips (FeroKap EP, producer Brněnské papírny, Brno, ČSSR). The glue strips remain effective at $0 \pm 5^\circ\text{C}$ for 2 years from date of production. The decrease in effectiveness towards the end of this period is insignificant ($P < 0.05$). Their use enables timely detection, monitoring of migration and seasonal dynamics, and reduction of the population density of the moths through systematic catching of the male. In the trial at Vitana Works, Prostějov, ČSSR a 90% reduction was obtained in the occurrence of the pests and in the losses caused by them.

CIGARETTE BEETLE PHEROMONE; A FIELD TRIAL STUDY.

D.K. Mueller, Insects Limited, Inc., 10505 North College Avenue, Indianapolis, IN 46280, USA.

Various traps baited with cigarette beetle pheromone (2,6-dimethyl-3,4 dihydro-2 H-pyran; Anhydroserricornin) were used to detect the presence and absence of hidden infestations in a pharmaceutical facility. The B.A.T. Lasiotraptm and the Serricotm trap caught the same number of insects. The B.A.T. Lasiotrap lures caught significantly more insects than the Serrico lures or the control. A dose response of the pheromone was tested in BioLuretm formulations to determine optimum release rates for the cigarette beetle. Formulations containing 1000 to 2000 micrograms/day of cigarette beetle pheromone caught the most insects.

PHEROMONE TRAPPING OF *PROSTEPHANUS TRUNCATUS* (HORN)

(COLEOPTERA : BOSTRICHIDAE) IN MAIZE FIELDS. Philip

Dobie*, Julie Dendy and Christine Sherman, Overseas

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For some years, commercially available traps baited with a single component of the aggregation pheromone of *P. truncatus* ("Trunc-call 1") have been used successfully for monitoring the presence of the beetle in maize stores. Recent experiments in Tanzania have shown that lures containing "Trunc-call 1" mixed with another pheromone component "Trunc-call 2" are very effective baits for trapping *P. truncatus* in maize fields.

FACTORS INFLUENCING EFFECTIVENESS OF SEX PHEROMONE-BAITED TRAPS IN THE STORAGE ENVIRONMENT. J.A. Coffelt* and R.R. Heath, USDA, ARS, Insect Attractants, Behavior and Basic Biology Research Laboratory, Gainesville, Florida, USA.

Sex pheromone-baited traps have been shown to be useful for monitoring populations of stored-product insects in storage environments. Behavioral studies with *Cadra cautella* (Walker) (Lepidoptera:Pyralidae) have shown the influence of quantitative differences in pheromone components upon trapping effectiveness.

Observations of male approach to, and landing in traps baited with *C. cautella* pheromones revealed that trapping efficiency (numbers of insects captured/numbers of insects that approached to within 0.3 or 0.6 m of a trap) was highly dependent upon pheromone release rate. Capture rates declined significantly when pheromone release rate was altered (increased or decreased) from the optimum level. The significance of these findings with regard to practical use of pheromones will be discussed.

DEVELOPMENT OF A PHEROMONE-TRAP MONITORING SYSTEM FOR SWEETPOTATO WEEVIL, *CYLAS FORMICARIUS ELEGANTULUS* (SUMMERS) (COLEOPTERA: CURCULIONIDAE). R.K. Jansson, University of Florida, I.F.A.S., T.R.E.C. Homestead, Florida 33031 U.S.A.

Sweetpotato weevil (SPW) is the most important pest of sweet potato worldwide. Even low level infestations may reduce yield because sweet potato produces terpenoids in response to SPW feeding. SPW is a pest of both field plantings and stored roots. The SPW threshold in storage in the U.S.A. is very low. For example, the contents of sweet potato packing houses infested with SPW have been burned to prevent the spread of SPW in Texas.

Recently, a female-produced sex pheromone that attracts only males was isolated, identified, synthesized, and bioassayed. Synthetic pheromone is currently being used in southern Florida to develop a pheromone-trap monitoring program for SPW in the southern U.S.A. and the Caribbean that is sensitive to regional differences in SPW densities and the needs of the sweet potato industry. Trap captures were positively correlated with pheromone dosage, negatively correlated with septa age, and affected by trap design. The potential of the pheromone for improving SPW management is immense.

PLODIA PHEROMONE TRAPPING TO DETECT MOTH INFESTATIONS IN A RAISIN MARKETING CHANNEL. E. L. Soderstrom*, R. T. Hinsch, A. J. Bongers, D. G. Brandl and H. Hoogendorn. USDA/ARS, Horticultural Crops Research Laboratory, Protection and Quarantine Research Unit. 2021 South Peach Avenue, Fresno, CA 93727.

Populations of stored-product moths in raisin marketing channels were evaluated with the pheromone (Z-E) 9-12 Tetradecadien-1-ol acetate. Sticky traps baited with this pheromone attracted Indianmeal moth, Plodia interpunctella (Hübner), almond moth, Cadra cautella (Walker), raisin moth, Cadra figuliella, Mediterranean flour moth, Anagasta kuehniella (Zeller), and tobacco moth, Ephestia elutella (Hübner). Indianmeal moth was found in very low numbers in a U.S. raisin processing plant. Raisin moths were plentiful outside the plant, but were rarely found inside the plant. During transport of raisins to Rotterdam, The Netherlands, only almond moths were captured in one of the 15 van-containers. Western European warehouses were infested with Indianmeal moth, tobacco moth, Mediterranean flour moth and almond moth. Only one raisin moth was trapped in these warehouses. Pheromone-baited traps are valuable for assessment of insect infestation in marketing channels and their use could lead to improved insect control programs and thus cleaner raisin products for the consumer.

ON-FARM TOBACCO STORAGE: INFESTATION BY CIGARETTE BEETLES (LASIODERMA SERRICORNE) AS ASSESSED BY PHEROMONE TRAPS. L. Ryan* and D. L. Faustini, Philip Morris USA, P.O. Box 26583, Richmond, Virginia 23261, USA.

The level of infestation of on-farm storage buildings by the cigarette beetle Lasioderma serricorne (F.) was monitored throughout the flue-cured tobacco harvest season using sex attractant-baited sticky traps. Fifty farms in fourteen counties in North Carolina and Virginia were monitored over a three month period. In six counties the tobacco was monitored in auction houses. The number of beetles are considered in relation to: quantities of tobacco stored over winter; construction and age of the storage building; progression of the harvest; North/South, East/West distribution and the insects life cycle. These findings are discussed in relation to on-farm storage of tobacco and post auction handling of the leaf.

CROSS REACTIVITY OF THE SCABIES MITE, *SARCOPTES SCABIEI*, AND THE HOUSE DUST MITE, *DERMATOPHAGOIDES FARINAE*. L.G. Arlian, Department of Biological Sciences, Wright State University, Dayton, Ohio 45435.

The purpose of this study was to evaluate the cross-reactivity of the ectoparasitic scabies mite, *S. scabiei* (SS), and the house dust mite, *D. farinae* (DF). Sera from *S. scabiei* infested rabbits contained antibodies that recognized at least 6 and 3 different antigens in extracts produced from DF body and DF fecal material, respectively. Likewise, rabbit antisera built to DF body and DF fecal extracts contained antibodies that recognized SS antigens. SDS-PAGE profiles of SS extract exhibited 30+ protein and peptide bands. Incubation of nitrocellulose strips containing SS bands with sera from 9 DF skin test positive patients with no history of scabies indicated 15 different SS bands bound IgE. The amount of IgE binding by the various SS bands varied both within and between patients. CRIE and western blotting using the sera of these patients revealed they also contained IgE directed at multiple DF antigens. These tests reveal that (1) the parasitic mite, SS, and house dust mite, DF, share a high degree of cross-reactivity, (2) house dust mite sensitive patients exhibit IgE that recognizes antigenic determinants on SS antigens, and (3) it is highly probable that scabies infested patients exhibit circulating antibodies built to SS but with Fabs that recognize DF antigens.

MANGE MITES : A PROBLEM ON PETS, AND SYSTEMATIC TREATMENT. E. Kutzer, Institute of Parasitology and Zoology, Vet. Med. University, 1030 Vienna, Austria.

Mange mites often cause serious diseases in domestic and wild animals which has frequently become both a great physical and economic problem. Specific treatment and the development of control-strategies are therefore necessary. Compounds administered perorally, pour-on or injected are better suited for these techniques due to several reasons. An appropriate compound for this control is the new endectocid ivermectin. On grounds of particular experiments on mange in domestic pig and wild boar periodical treatments and measures of disinfection (in the domestic pig only) resulted in an eradication of this disease.

THE FAUNAL STUDY OF STORED PRODUCT MITES ATTACKING FOOD IN CHONGQING, CHINA. L.S. Li* and J.Y. Xuan, Department of Plant Protection, S.W. Agricultural University, Chongqing, Sichuan, China.

An investigation of the specific pests, mites and fungi of 51 kinds of food had been made in 1984-1986 in Chongqing, Sichuan, China. Among the collected samples, 14 species of mites on 21 kinds of food were found. The injury and habits of the major species and the controlling methods were studied and discussed.

EVOLUTION OF GLYCYPHAGOID MITES IN ASSOCIATION WITH HUMANS AND OTHER MAMMALS. B.M. O'Connor, Museum of Zoology and Department of Biology, The University of Michigan, Ann Arbor, Michigan, USA, 48109.

The Glycyphagoidea is one of the most diverse groups of mites inhabiting stored products. This diversity consists almost exclusively of species which invaded such habitats from mammal nests. Prior classifications of these mites do not reflect phylogenetic relationships adequately, making hypotheses of historical ecology impossible. A new phylogenetic hypothesis is presented at the generic level which recognizes only monophyletic taxa. This phylogeny suggests that the evolution of the Glycyphagoidea may be viewed as a combination of cospeciation events with mammalian hosts and colonization events leading to new host associations. Evidence suggests that this lineage of mites has been associated with the Mammalia since the Mesozoic. Colonization events have most commonly resulted in mites transferring to rodents from other mammalian groups. Almost all of the species now associated with human habitations and stored products originated with rodents although in many instances, the rodent association was already a secondary one.

STORED PRODUCT MITES: MANAGEMENT OF ASSOCIATED MICROFAUNA IN PROCESSED FOOD.

J. G. Rodriguez* and M. F. Potts, Department of Entomology, University of Kentucky, Lexington, Kentucky 40546-0091.

The purpose of this study was to evaluate two stored-product acarid mites - *Tyrophagus putrescentiae* and *Caloglyphus rodriguezi* - in their tolerance to microfauna associated with stored or processed food products. Twenty two species of fungi and five species of *Lactobacillus* were examined for survival and reproduction, with the individual microorganisms as the only nutritive source for the mites. A tolerance for mycotoxin-producing fungi or other contaminating bacteria by a mite species indicates that a potential for vectoring the contaminant existed. There were considerable response differences between the two species of mites with *C. rodriguezi* being generally more tolerant than *T. putrescentiae*. This was particularly noticeable when fed *Lactobacillus* species. The various *Aspergillus flavus* strains were generally inhospitable or deadly to both mite species.

DYNAMICS OF ACARINE POPULATIONS IN STORED-OAT ECOSYSTEMS - A MULTIVARIATE STUDY. R.N. Sinha, Agriculture Canada, Research Station, Winnipeg, Manitoba, Canada, R3T 2M9

Comparative population fluctuation patterns were determined during 1978-84 in two farm-stored oat bulks, one containing hullless Terra oats, the other hulled Random oats, for seven kinds of mites. While both bulks were naturally infested with mites, population levels were higher, and the quality of grain as measured by fat acidity values lower in the hullless oat than in the hulled oat bulk. *Lepidoglyphus destructor* was the most abundant mite species; other mites included *Acarus siro*, *Cheyletus eruditus*, *Tarsonemus*, *Tydeidae* and *Mesostigmata*. Principal component, multiple regression and discriminant analyses of the data revealed characteristic interrelation patterns for each kind of mite.

JUVENILE HORMONE ANALOG EFFECTS ON THE NORTH AMERICAN HOUSE DUST MITE, *DERMATOPHAGOIDES FARINAE* (ACARI: PYROGLYPHIDAE). Amy L. Suggars*, C.G. Wright and M.H. Farrier, Dept. of Entomology, North Carolina State University, Raleigh, North Carolina, USA 27695-7613

Juvenile hormone analogs (JHAs) have been used in recent years to control such household pests as German cockroaches and cat fleas. The purpose of this investigation was to assess the potential of JHAs for controlling populations of house dust mites. Concentrations from .1% to 5% active ingredient (A.I.) of five JHAs (methoprene, hydroprene, fenoxycarb, dimilin, and alsystin) were initially screened. Of these, only methoprene and hydroprene, at concentrations above 1% A.I., significantly suppressed house dust mite population growth. Additional experiments were conducted with these two compounds to determine further effects on the growth, development and reproduction of house dust mites.

POST-RADIATION CHANGES IN SPERMATOGENESIS IN *ACARUS SIRO* (L.). J. Boczek* and E. Szlendak, Department of Applied Entomology, Agricultural University of Warsaw, Nowoursynowska 166, 02-766 Warszawa, Poland

Mating behaviour, production and transfer of spermatophores in mites treated with fast electrons were observed. The radiation adversely affected the sexual behaviour but did not eliminate it. Twelve days after treatment with 1 kGy the testes could not be recognized, probably due to atrophy. In mites, treated with lower doses the process of spermatogenesis was only temporarily stopped. Gonial cells showed necrosis and ultrastructural changes. The radiation induced dilatation of endoplasmic reticulum and the disruption of mitochondrial cristae leading to vacuole formation. These ultrastructural post-radiation changes are one of the major reasons of mites' sterility. Damages of mitochondrial cristae in developing cells caused a retention of spermatogenesis and diminishing the number of spermatids in treated mites.

REPRODUCTIVE POTENTIAL, SEX RATIO, AND MATING EFFICIENCY OF *PYEMOTES TRITICI* (ACARI: PYEMOTIDAE). William A. Bruce, Stored-Product Insects Research and Development Laboratory, USDA-ARS, P. O. Box 22909, Savannah, GA 31403 USA, and Dana L. Wrensch*, Department of Entomology, The Ohio State University, Columbus OH 43210 USA.

Two studies of the reproductive potential of *Pyemotes tritici* were undertaken to evaluate its capabilities as a biological control agent. Study 1 measured daily and total progeny size and sex ratio from 128 isolated gravid females. In study 2, mating ability of 25 males was evaluated by supplying each male with a continuous series of virgin females until the males died. Number of matings/male was noted and the interval between consecutive matings was timed. Mated females were individually isolated. A total of 446 matings was scored for progeny size and sex ratio. Females produced an average of 254.19 offspring of which only 8.67% were male. Males emerged faster than females and over 50% of total progeny emerged in the first 6 days. Mating *per se* appears to potentiate fecundity because total offspring produced/female decreases significantly with mating order. The reproductive potential of *P. tritici* is very high: from data obtained, "r", the intrinsic rate of increase, is estimated to be 0.61 (time in days). Thus *P. tritici* has a much higher innate capacity for population growth than does any host for which it might be employed in biocontrol.

STORED PRODUCT AS ENEMY-FREE SPACE FOR MITES. U. Gerson, Division of Biological Control, Department of Entomology, University of California, Riverside, CA 92521, USA.

Different predators prey on stored product pest mites in their natural habitats and in granaries. It is postulated that the failure of many field predators to colonize stored product has provided the pests with "enemy-free space". Efforts should therefore be made to search for and introduce additional predaceous mites. Available lists of stored product mites from different parts of the world could provide a beginning for such efforts.

Potential Of Biological Control For Management Of Stored-product Pest Populations

POTENTIAL OF BIOLOGICAL CONTROL FOR STORED-PRODUCT PESTS WITH SPECIAL REFERENCE TO PARASITES OF THE STORED-PRODUCT MOTHS. John H. Brower, Stored-Product Insects Research and Development Laboratory, ARS, USDA, P. O. Box 22909, Savannah, GA 31403 USA.

Research on the potential of biological control for suppression of stored-product pests has been limited until recently. However, increasing problems with chemical methods has led to new interest in using biological controls as part of an integrated control approach to stored-product pest management. A variety of parasites and predators attack all species of stored-product pests. Various groups of the parasitic Hymenoptera are the major enemies of these pests, especially of the Lepidoptera. Laboratory studies showed that these parasites are often quite host specific, and they are well adapted to finding and parasitizing their respective hosts in a storage environment. Two or more complementary parasites can often be chosen for a greater efficiency of control, and reductions in host populations can be complete or nearly complete. Several different parasite release strategies are possible, and small scale field studies have demonstrated the efficacy of the inundative release technique for suppression of stored-product pests.

INTRA- AND INTERSPECIFIC LARVAL COMPETITION AMONG THE PARASITIC WASPS ON BRUCHIDAE. K. Fujii* and M. W. Khin, Institute of Biological Sciences, University of Tsukuba, Tsukuba, Ibaraki 305 Japan

Super- and multiparasitism occurs when female wasps are abundant relative to the available hosts. We studied the effect of oviposition time-lags on the outcome of con- and heterospecific larval competition, using three wasp species (*Dinarmus basalis*, *Anisopteromalus calandrae*, and *Heterospilus prosopidis*), ectoparasitic on the larvae of Azuki bean weevil (*Callosobruchus chinensis*).

We made acrylic plates with wells and transferred a parasite egg onto a host inside the well, followed by a con/heterospecific egg after predetermined periods. Only a single adult wasp emerged. Young active larvae aggressively attack one another. However, with larger time-lags the occupant may have used so much of the host that the invader starves without a fight. Thus, interference competition operates with small time-lags and exploitation competition with larger time-lags.

In interspecific competition, an increasing time-lag always increases the advantage of the occupant. However, in intraspecific competition, there are dramatic reversals of advantage with increasing time-lags. At 24 hrs the occupant is favored, at 48 hrs the invader almost exclusively wins, but at 72 hrs the occupant is almost always the survivor again. We hypothesize that although wasp larvae can recognize active young heterospecific larvae and all conspecific larvae as competitors they do not recognize the later instars of heterospecific.

PREDATORY HEMIPTERA AS CONTROL AGENTS FOR STORAGE PESTS.

R. T. Arbogast, Stored-Product Insects Research and Development Laboratory, Agricultural Research Service, U. S. Department of Agriculture, P. O. Box 22909, Savannah GA 31403.

A number of true bugs (Hemiptera) of the families Anthracoridae and Reduviidae have been recorded as predators in storage ecosystems. Studies of the anthracorid *Xylocoris flavipes* (Reuter) have indicated that these bugs could have considerable potential as control agents for storage insect pests, but their biology and especially their role in regulating pest populations have been largely neglected. The effectiveness of *X. flavipes* in regulating pest populations has been demonstrated in a number of small scale experiments. Its biology and prey relationships have been extensively examined and can be used as a basis of comparison in making preliminary evaluations of other predatory storage Hemiptera. The life history features of other species for which sufficient information is available are compared with those of *X. flavipes* and a preliminary assessment made of their potential as biological control agents.

RESISTANCE OF STORAGE PESTS TO *BACILLUS THURINGIENSIS*.

W. H. McGaughey, U.S. Grain Marketing Research Laboratory, USDA, ARS, 1515 College Avenue, Manhattan, Kansas 66502.

Insect resistance to the spore-crystal protein complex of *Bacillus thuringiensis*, the most widely used and intensively studied microbial insecticide, has been presumed to be unlikely to occur. However, I have shown that *Plodia interpunctella*, a major lepidopteran pest of stored grain, can develop high levels of resistance to the HD-1 strain of *B. thuringiensis* within only a few generations. The capacity for resistance has been present in all insect strains tested, although the rates of development of resistance under laboratory selection have differed among the strains. The resistant insects are cross-resistant to many but not all isolates of *B. thuringiensis*. They are susceptible to the β -exotoxin and to the crystal protein of several non-exotoxin-producing isolates. The potential for insect resistance to other toxins or isolates is not known. The practical implications of *B. thuringiensis* resistance in grain storage and other pest insects will be discussed.

PROTOZOANS AS LIMITING FACTORS IN POPULATION DYNAMICS OF *TRIBOLIUM* SPP. AND *EPHESTIA* SPP. J.J. Lipa (Poland)

No Abstract

THE POTENTIAL OF INSECT GROWTH REGULATORS IN THE SUPPRESSION OF STORED PRODUCT INSECT POPULATIONS.

M. Bengston, Entomology Branch, Department of Primary Industries, Meiers Road, Indooroopilly, Brisbane, Australia 4068.

Several insect growth regulators including both juvenile hormone analogues and chitin inhibitors have been studied in relation to stored product insects. The response of individual species varies widely and the response of *Sitophilus* spp is generally slight.

Data indicate that insect growth regulators will be useful in suppressing insect populations in stored commodities where *Sitophilus* is not a major problem. Extensive studies in Australia have suggested that methoprene in combination with conventional organophosphorus pesticides will provide effective control of the pest complex in stored cereals.

Potential Of Biological Control For Management Of Stored-product Pest Populations

AMYLASE INHIBITORS IN CEREALS AS BIOCHEMICAL RESISTANCE FACTORS AGAINST SITOPHILUS WEEVILS. J.E. Baker* and S.M. Woo, Stored-Product Insects Research and Development Laboratory, USDA-ARS, Savannah, GA 31403 USA

Alpha-amylase is a predominant digestive hydrolase in Sitophilus weevils. Multiple allozymes are present in S. oryzae and S. zeamais. Crossing experiments indicate that at least two autosomal structural genes code amylase in S. zeamais, with evidence for gene duplication in one geographic strain. Significant strain x diet interactions occur in modulating amylase levels in both species. Levels are highest in barley and rice-fed weevils, intermediate in maize-fed weevils, and lowest in wheat-fed weevils. Low amylase levels in wheat-fed weevils are apparently due to ingestion of the complex of naturally-occurring amylase inhibitors present in wheat. A strain low in amylase produced fewer progeny and developed slower in wheat. One inhibitor protein purified from wheat forms a tightly-bound ($K_i=0.07\text{nM}$), electrophoretically-stable, inactive protein-protein complex with amylases from S. oryzae. A second inhibitor is a noncompetitive inhibitor ($K_i=11\text{nM}$ and 4nM against the two allozymes of S. oryzae). Wheat varieties genetically-modified to increase inhibitor levels may be useful in a biological control program to suppress population development of these major pests of stored grain.

BIOLOGICAL CONTROL AGAINST MITES IN STORED-FOOD.
E. Zdarkova (Czechoslovakia)

No Abstract

BIOLOGY AND PREDATORY ABILITY OF TERETRIOSOMA NIGRESCENS LEWIS (COLEOPTERA: HISTERIDAE) A PREDATOR OF PROSTEPHANUS TRUNCATUS (HORN) (COLEOPTERA: BOSTRICHIDAE). D P REES, Overseas Development Natural Resources Institute, Storage Dept., London Road, Slough, Berks. SL3 7HL, U.K.

T. nigrescens is a predatory beetle associated with P. truncatus in Central America but not Africa. Both adults and larvae of the predator prey on juvenile stages of P. truncatus; the adult can survive, but not breed, for up to a year on frass and grain debris.

Over 14 weeks at 27°C , 70% rh, the rate of increase of 3 pairs of P. truncatus infesting a maize cob was reduced by a factor of ten by the addition of 4 adult T. nigrescens. Little interaction was noted between the predator and the beetle pests Sitophilus zeamais and Tribolium castaneum. T. nigrescens reduced population growth of P. truncatus on maize as dry as 8.5% mc.

The aggregation pheromones of P. truncatus and other, as yet unidentified, substances appear to act as kairomones to T. nigrescens, possibly assisting it to find its prey.

Dynamics And Mathematical Modelling Of Stored-product Insect Populations

No Abstracts

A COMPUTERIZED ACOUSTICAL DETECTION SYSTEM FOR MONITORING LARVAE IN GRAIN AND OTHER POST-HARVEST COMMODITIES. J.C. Webb*, D.C. Slaughter and C.A. Litzkow, USDA, ARS, Insect Attractants, Behavior and Basic Biology Research Laboratory, Gainesville, Florida, USA.

The detection of hidden insects in grain and other post-harvest commodities has long been a problem. The system described in this paper can detect, monitor and store data of the feeding and moving sounds of stored grain insect larvae in a kernel of grain and other insect larvae feeding sounds in commodities such as grapefruit, apple, oranges, etc. Two types of detectors have been developed for this system. One detector is based on the organ pipe principle with a thin membrane attached to one end of a pipe and the transducer to the other. The other detector was developed using a piezoelectric transducer. The signal from these transducers are amplified, filtered and then digitized and stored in a computer. Software has been developed so that it can be used on any IBM compatible computer.

SOUND-DETECTION OF STORED-PRODUCT INSECTS THAT FEED INSIDE KERNELS OF GRAIN. K.W. Vick* and J.C. Webb, USDA, ARS, Insect Attractants, Behavior and Basic Biology Research Laboratory, Gainesville, Florida, USA.

A system for acoustically detecting internal-feeding insect larvae in grain is described. Larvae of the lesser grain borer, *Rhyzopertha dominica* (F.); rice weevil, *Sitophilus oryzae* (L.); and Angoumois grain moth, *Sitotroga cerealella* (Olivier), produced sounds loud enough to be detected 13 to 19 days after oviposition, depending upon the species. After first detection, larvae produced detectable sounds 71 to 90% of the time until pupation. Infestation rates could be quantified, at least in the range of 1 to 20 infested kernels per 100 ml of grain, where the infestation rate was strongly correlated to number of sounds as counted by a frequency counter. Factor effecting sensitivity of the system will be discussed.

LARGE SCALE INSECT SURVEY OF GRAIN STORED IN FARM BINS ON SOUTHERN MANITOBA, USING A PLASTIC TRAP. F. J. Madrid* and S.R. Loschiavo, Agrobiotech International Incorporated, Winnipeg, Manitoba, Canada R3T 3L4.

Analyses of trap contents obtained sampling different types of cereals stored in 110 farm bins located on the grain growing region of Southern Manitoba and surveyed twice per year during 1986-1987 are presented. After trap retrieval, adult insects were counted and identified. Percentage of bins showing presence of insects varied from 36% in barley and 40% in wheat to 80% in oats. The most common species collected were *Cartodere constricta* (Gyll.), *Cryptophagus* sp., *Lachesilla* sp., *Ahasverus advena* (Waltl) and the primary feeders *Cryptolestes ferrugineus* (Stephens) and *Tribolium castaneum* (Herbst). These six pests were found on 20%, 7%, 11%, 5%, 14% and 3% of all bins sampled. During 1986, bins equipped with aeration systems amounted to 26.4% of all infested bins.

DETECTION, DISTRIBUTION AND SEASONAL ABUNDANCE OF *SITOTROGA CEREALELLA* AND *RHYZOPERTHA DOMINICA* AS INDICATED BY PHEROMONE-BAITED ADHESIVE TRAPS. R. R. Cogburn, U.S. Department of Agriculture, Agricultural Research Service, Beaumont, Texas, USA, 77706.

A sex pheromone of *S. cerealella* and an aggregation pheromone of *R. dominica* were used to assess the abundance and distribution of these species in different environments. Farm storages, commercial drying and storage units, mills, agricultural land and woodland were sampled. Both species were detected in all environments, however, different levels of abundance were observed within and between environments. For example, the number of *R. dominica* caught per trap per year at 12 different farms ranged from 82 to 981. Both species were detected by traps in grain fields. Captures of *S. cerealella* increased abruptly when the grain headed but captures of *R. dominica* did not. Apparently, *S. cerealella* sought out and infested standing grain. In general, both species appeared in early spring, peaked in mid-summer and declined thereafter. However, population trends at different locations were influenced by local conditions. In woodland, a low-level population was observed throughout spring and summer but a dramatic increase occurred in the fall and persisted until cold weather reduced captures to zero.

DEVELOPMENT OF AN INSECT MONITORING SYSTEM FOR UNDERGROUND GRAIN STORAGE. F.V. Dunkel, Underground Space Center, Department of Civil and Mineral Engineering, University of Minnesota Minneapolis, Minnesota U.S.A. 55455.

Underground airtight storage of grain, beans and other agricultural commodities has certain advantages. Quality of the commodity can be maintained without the addition of pesticides or energy for aeration. Structures can be built at lower costs (in the USA, one-third less) than aboveground because support materials are the earth itself. Our data indicate that insects will not enter or develop in such storages unless the seal is broken. It is, never-the-less, important to monitor insects in these storages because resistance to these low oxygen/high carbon dioxide environments has been recorded for *Sitophilus granarius* (L.) (Bond and Buckland 1979) and because ideally these storages are kept sealed for one to five years. Insect monitoring systems have been developed and tested in shelled corn for 36 months in Minnesota, in dry edible beans (*Phaseolus vulgaris* L.) for 18 months in Rwanda (eastcentral Africa), and for 3 months in barley and 6 months in durum wheat in Morocco. Pitfall traps were not successful. Aerial trapping of Lepidoptera was not possible because there must be no airspace in these storages. Sieving of grain from destructive sampling has been relied on as well as indirect detection methods such as remote sensing of ZRH and temperature. Acoustical signal systems need to be developed for this storage type. Another solution which is being investigated is insulated conduits equipped with airlocks.

DEVELOPMENT OF A NEW TRAP FOR DETECTION AND MONITORING THE KHAPRA BEETLE, *TROGODERMA GRANARIUM* EVERTS (COLEOPTERA: DERMESTIDAE). A.V. Barak, USDA, APHIS, PPQ, 209 River Street, Hoboken, NJ 07030.

A new vertically arranged wall mounted trap made of corrugated paper was designed for USDA, PPQ Khapra beetle (KB) detection programs. The new trap uses a membrane type 6 month sex pheromone lure and wheat germ oil (WGO) as a larval attractant. Oils of oat, sesame and pumpkin were more attractive than WGO when fresh, but WGO was the most attractive as the oils aged. The KB trap caught 3.4 times as many larvae over 5 days and 4.9 times as many adults in one day compared to the flat type trap. The problem of trapped insects loose in the trap but not caught in the clear plastic collection tray was solved by a better arrangement of attractant components, with the pheromone lure positioned directly over the collection tray containing WGO. A functional trap jacket with fold out flaps was designed to give insects improved entry into the trap, provide direct access to the collection tray and allow intimate contact with the wall surfaces when mounted with foam tape. Wall mounted traps did not catch larvae or adults unless the flaps were deployed. KB traps wall mounted at floor level also effective, but catch was improved (P=0.13) by opening rear flaps to bridge the wall/tape gap.

ROLE OF ESTIMATION AND PREDICTION OF INSECT POPULATIONS IN IMPROVING PEST MANAGEMENT. D.W. Hagstrum, USDA, ARS, U.S. Grain Marketing Research Laboratory, Manhattan, Kansas.

Quantitative studies of the statistical distribution of stored-grain insects among samples provides insights into the relationships between insect density, sampling effort and accuracy of estimation of insect density. Each doubling of the sampling effort resulted in a 2.8-fold reduction in the lowest density of insects estimated with an accuracy specified as a percentage of the mean. Such insights are used to show how management of stored grain insects might be improved by increased sampling effort. With increased sampling effort, insect populations can be estimated at lower densities earlier in the storage period. With earlier estimation of insect populations and models that predict future insect populations, managers can anticipate when populations will reach economically important levels, more efficiently schedule insect control and reduce the frequency at which grain needs to be sampled for insects.

DETECTION OF HIDDEN INSECT INFESTATIONS BY INFRARED CARBON DIOXIDE GAS ANALYSIS: AN UPDATE. William A. Bruce, Stored-Product Insects Research and Development Laboratory, ARS, USDA, P. O. Box 22909, Savannah GA 31403 USA.

A patented system for detecting insect infestations in agricultural commodities by infrared carbon dioxide (IRCO₂) gas analysis has been tested under limited field conditions. Results indicate that this method is significantly better than current inspection procedures. The system is not limited to the detection of insects, but is adaptable to any CO₂-producing organism and has been modified recently to detect contraband materials by US Customs. Prototype configurations of the system have been fabricated but virtually none is in use today. Suggested reasons for the lack of acceptance are discussed.

CAN STORED-PRODUCT INSECTS DEVELOP RESISTANCE TO MODIFIED ATMOSPHERES? E. Donahaye, Department of Stored Products, Agricultural Research Organization, Bet Dagan 50-250, Israel.

Modified atmospheres have been proposed as alternatives to fumigants for controlling stored product pests. However, the possibility that these insects will become adapted to, or develop resistance to modified atmospheres cannot be ruled out.

Studies on the development of resistance to high carbon dioxide concentrations by strains of *Sitophilus oryzae* and *Tribolium castaneum* under laboratory conditions are discussed. Similarly, the development of a strain of *T. castaneum* resistant to low oxygen concentrations is described.

Findings on *T. castaneum* indicate a multiplicity of genetic factors contributing together towards a general physiological and biochemical adaptation of the selected insects to the stress of high carbon dioxide and low oxygen concentrations.

It is proposed that the laboratory selected strains are in the process of developing metabolic compensations. The role of such compensations in the development of resistance to modified atmospheres is discussed.

USE OF HIGH TEMPERATURE FOR THE ELIMINATION OF DRYWOOD TERMITES. Walter Ebeling*, University of California at Los Angeles, Los Angeles, CA 90024 and Charles F. Forbes, California State University, Dominguez Hills, CA 90747, U.S.A.

Insects have a remarkably limited tolerance for temperatures either below or above their normal range. The western drywood termite, *Incisitermes minor*, dies in about 5 minutes at -20°C or 55°C. High temperatures lethal to termites were generated in tarp-covered buildings by heating air with a salamander-type heater, using propane gas for fuel, and conducting the hot air throughout the building with light, flexible ducts. A heat-resistant fan in every room prevents heat stratification. A room temperature of ca. 66°C is required to penetrate the walls and wood structures to bring lethal temperatures to termite galleries within a reasonable period. The object is to subject the termites to a temperature of 49°C or more for at least 30 minutes. The center of a sill plate resting on concrete can be heated to 49°C in about 6 hours. This is usually the last place in a typical California dwelling to reach lethal temperatures. In "spot treatments," as in the treatment of one wall, the centers of sill plates on concrete slabs have been heated to 49°C in from 1.5 to 3 hours.

EFFECT OF LIGHT ON THE DEVELOPMENT OF THE GRANARY WEEVIL, *SITOPHILUS GRANARIUS* L. (COLLEOPTERA: CURCULIONIDAE). I.I. Ismail*, M.A. Ewies, Soheir R. Souka and Mai S. El-Degwy, Department of Economic Entomology & Pesticides, Faculty of Agriculture Cairo University, Cairo, Egypt.

The effect of light on the development of the granary weevil, *Sitophilus granarius* (L.) was studied. Three different light conditions, i.e. continuous light (LL), continuous darkness (DD) and natural illumination (LD) were used. LL light regime delayed egg laying and hatching. Number of larvae that reached adult stage under (LL) was less than under either (LD) and (DD). Also LL increased the larval period. LD light regime stimulated rapid emergence of adults from the grains. Adults bred under LL and DD regimes lived longer than those under LL regime. The average total number of eggs per female decreased significantly under LL regime. Light has no significant effect on growth of both males and females of *S. granarius*. The complete life cycle was longer for insects bred under LL than those under LD and DD during all generations.

DISINFESTING DRIED FRUITS OF *CARPOPHILUS* SPECIES WITHOUT USING FUMIGANTS. S. Navarro* and E. Donahaye, Department of Stored Products, Agricultural Research Organization, The Volcani Center, Bet Dagan 50 250, Israel.

Several *Carpophilus* species are among the most important pests of dried fruit, and particularly of dates at the time of harvest. Upon arrival at the packing stations, dates are fumigated with methyl bromide to disinfest them and to control the insect population. However, the unique properties of and inherent advantages to this fumigant are under careful consideration because of the occurrence of insect resistance, and restrictions related to the undesirable effects of its residues.

The mechanism of this disinfestation effect, which causes the active insect stages (larvae and adults) to abandon the dates before they succumb, is not yet clear. However, recent studies in our laboratory have shown that non-toxic treatments incorporating modified atmospheres and low pressures were also effective in achieving disinfestation of *Carpophilus* spp. larvae and adults. Disinfestation of naturally and artificially infested dates was examined using CO₂, 3% O₂ in a nitrogen atmosphere, and low pressures. These treatments were compared with the effect of methyl bromide alone or in combination with CO₂ or at 100 mm Hg pressure. The results demonstrated the effectiveness of disinfesting dates by these non-toxic treatments.

EFFICACY OF GAMMA RADIATION FOR CONTROL OF INDIAN MEAL MOTH (LEPIDOPTERA: PYRALIDAE) IN DRIED FRUITS AND NUTS. J. A. Johnson. USDA-ARS, Horticultural Crops Research Laboratory, Fresno, Calif. 93727

We studied the feasibility of gamma radiation for control of postharvest infestations of the Indian meal moth (IMM), *Plodia interpunctella* (Hübner), in dried fruits and nuts. Posttreatment development, feeding and mortality of IMM larvae irradiated with from 14.9 to 62.7 krad was determined. The fertility of irradiated IMM adults and pupae and the fertility of their progeny was also examined.

All doses prevented adult emergence from irradiated IMM larvae. Longevity of young larvae was reduced from that of controls; longevity of older larvae was increased. Weight gain and food consumption of irradiated larvae were reduced, indicating that while mortality may be delayed, damage from feeding would be reduced. Doses of 59.4 krad or higher caused abnormal adult emergence from irradiated pupae, resulting in deformed, nonviable adults. Females from pupae irradiated with 26.9-31.9 krad or higher prevented reproduction of irradiated adults. Progeny of irradiated parents also showed a high degree of sterility. Doses of 30-45 krad, therefore, provided efficacious control of postharvest IMM infestations of dried fruits and nuts.

IRRADIATION DISINFESTATION OF BROAD BEAN SEEDS DURING STORAGE IN EGYPT(*), E.A. Elkady and A. M. Hekal, Department of Plant Protection, Faculty of Agriculture, Ain Shams University, Cairo, Egypt.

The Three treated doses 400, 600 and 800 Gray were efficient to kill the larvae and pupae of both *Bruchidius incarnatus* and *Bruchus rufimanus* inside the broad bean seeds after irradiation directly and the successive observations. Also the same effect was pronounced in case of non emerging adult stages of *B. incarnatus*.

On the contrary, alive adults of *B. rufimanus* were not found in the control, where dead non emerging adults were found in all the four different treatments, i.e., 400, 600 and 800 Gray.

It could be suggested that irradiation disinfection of broad bean seeds could be achieved by using 400 Gray only, provided that we collect the living adults from seeds before the irradiation process by suitable sucking machine.

(*) Supported by IAEA. Vienna. AUSTRIA.

THE MANAGEMENT OF INSECTICIDE RESISTANCE IN STORED GRAIN PESTS: THE ROLE OF TEMPERATURE. B.C. Longstaff, CSIRO Division of Entomology, G.P.O. Box 1700, Canberra, ACT 2601, Australia

The grain storage environment is unusual from the management point of view in that it is often possible to use temperature manipulation to slow down or prevent population growth of insect pests. Under Australian conditions, grain cooling by itself is not able to prevent pest population growth and insecticides remain the principal agents for control of insect pests. These are frequently used together with grain cooling, because chemical breakdown is reduced at lower temperatures and application rates may be reduced accordingly.

Because temperature affects all aspects of population growth, see original, a profound effect upon generation time and thus the rate of spread of insecticide resistance. The results of a series of simulations are presented where various aspects of this relationship are considered. These include the rate of cooling, the rate of change of gene frequency, the changes in dose required to achieve control, and the expression of resistance. The consequences of these results for the management of insecticide resistance are discussed.

RECENT ADVANCES IN MODELLING THE STORED GRAIN ECOSYSTEM FOR ENHANCED CONTROL OF STORED PRODUCTS COLEOPTERA. G. R. Thorpe* and S. G. Wilson, CSIRO Division of Entomology, P.O. Box 26, Highett, Victoria, Australia 3195.

Recent developments in the formulation and solution of mathematical models of the stored grain ecosystem have enabled the simulation of some of the complex interactions that occur between physical and biological phenomena. For example, the movement of moisture and fumigants by free convection can be modelled, and their impact on population of stored product pests estimated. Two-dimensional models of aerated and drying grain have also been developed which similarly enable the stored grain ecosystem to be modelled in far greater detail than previously possible. In particular, the condition of the grain close to the walls of grain stores can be simulated. The work suggests the possibility of devising an aeration control strategy that results in warm arid regions close to the wall, and cooler wetter regions in the grain bulk; both conditions are inimical to insect population growth. The models are being developed in the form of easy-to-use packages to assist in the control of stored products pests.

DYNAMICS OF GRANARY BEETLE POPULATIONS AND CHANGES OF SEX RATIO: SIMULATION MODEL APPROACHES. Z. Ciesielska, Institute of Biology, Pedagogical University, Podbrzezie 3, 31-054 Kraków, Poland.

Modification in the primary sex structure of population with the equal sex ratio ($\frac{m}{f}=1$) takes place mainly because of the various mortality of males and females at the later stages of development. Such changes do not occur at the earlier stages so often. Sex ratio of population can also undergo certain changes caused by different growth rate of males and females. The domination of one sex in the class of mature individuals can affect the dynamics of population. In experimental populations of granary beetles the processes of change are more easily observed. In *O. surinamensis*, *R. dominica*, *S. granarius* and *S. oryzae* there exists negative feedbacks between sex ratio and number of individuals for instance in unfavourable conditions, in interspecific competition etc. Changes in sex ratio are considered to be one of the mechanisms of the regulation of population numbers. The models of processes have been elaborated.

A SIMULATION MODEL OF POPULATION DYNAMICS OF THE RUSTY GRAIN BEETLE, *CRYPTOLESTES FERRUGINEUS* (STEPHENS) (COLEOPTERA: CUCUJIDAE), IN STORED WHEAT. H. Kawamoto*1, R.N. Sinha2, W.E. Muir1, S.M. Woods2. 1) Agricultural Engineering Department, University of Manitoba, Winnipeg, Manitoba, Canada, R3T 2N2; 2) Agriculture Canada Research Station, Winnipeg, Manitoba, Canada, R3T 2M9.

A simulation model of the population dynamics of the rusty grain beetle, *C. ferrugineus*, in stored wheat was constructed using published data by several authors. The model consists of submodels of development of eggs and immatures, mortality, and oviposition. An equation of Sharpe and DeMichele (1977) was expanded to describe the immature developmental rate at various temperatures and relative humidities. A distribution function by Weibull (1951) was modified and expanded to describe the oviposition rate of females of various ages at various temperatures, relative humidities and adult densities. Trial simulations show that temperature, and to a lesser extent relative humidity, were the most important factors regulating the population growth of *C. ferrugineus*.

ADDITIONAL EVIDENCE OF THE UNIVOLTINE LIFE CYCLE OF *CALLOSOPRUCHUS CHINENSIS* (L.) (COLEOPTERA: BRUCHIDAE) IN FIELD. K. Shinoda*, T. Yoshida and S. Baba, Laboratory of Applied Entomology, College of Agriculture, Okayama University, Okayama 700, Japan.

Hitherto it was believed that *Callosobruchus chinensis* is multivoltine: has many generations under storage conditions and the wild life cycle of the species was unknown although it was found weevils visit bean field and oviposit on the growing pods. We found the weevils also visit wild legumes and deposit their eggs on these pods and assumed the larvae overwinter on the wild beans and the adults emerge in spring, exist especially on pollen and water throughout summer, and in autumn visit the legumes to wait their flowering and fruiting. There might be one generation a year for the wild population. Then a wild colony of *Vigna trilobata* infested by the weevil was covered with cheese cloth in mid-April and the newly emerged adults were collected inside the cloth: the hypothesis of weevil overwintering in the field conditions was verified. Next, thirty thousand of newly emerged adults from stock culture were marked with enamel paint and released in the field from late May to early June. In late October one the marked adult was captured in bean field. The weevils were confirmed to be alive for four months in the field.

GEOGRAPHICAL DISTRIBUTION OF THE ALLIED SPECIES INFESTING STORED PRODUCTS. T. Yoshida, Laboratory of Applied Entomology, College of Agriculture, Okayama University, Okayama 700, Japan.

<Problem> On the analysis of the domestication of Sitophilus granarius I concluded the species became pest of stored barley or wheat in Near East. The specimen of the species was found in ancient Egyptian tombs. Nevertheless now the species is a serious pest with a preference for the more temperate regions north of 40 degrees latitude. Why is that?

<Solution> The species perhaps originated in warm climate region and the original size was rather small: the specimen found in the tomb was smaller than average for the species. The larger strain adapted to cooler climate evolved from the ancient and disperse to northern part with the expansion of wheat cultivation to north.

<Expansion> A hypothesis is possible. The species originated in warm region has a larger allied strain or species adapted to cooler climate. The allied extend their distribution to northern region. The distribution, small species in southern part and larger species in northern part, is found on the allied species. The hypothesis is proved by the evidences for Alphitobius, Cryptolestes, Gnathocerus, Sitophilus and Tribolium spp.

THE CONTROL OF INSECTS IN EXPORT GRAIN. D R Wilkin*, K M Amos and K P Thomas. Ministry of Agriculture, Fisheries and Food, Agricultural Development and Advisory Service, Slough Laboratory, London Road, Slough, Berkshire, England, SL3 7HJ.

The effectiveness of chlorpyrifos-methyl, etrimfos, methacrifos and pirimiphos-methyl was assessed against five species of insects at temperatures of 5, 10, 15 and 20°C. The pesticides were applied at the full, half and a quarter of the normal dose recommended by the manufacturer. The insects tested were laboratory strains of multi-organophosphorus resistant *T.castaneum*, *C.ferrugineus*, *S.granarius* and *O.surinamensis* and a strain of *A.advena* of unknown resistance status. The assessments were generally carried out over a period of ten days or until 100% mortality was reached. At 20°C, the full dose of all pesticides gave complete kill of all species in 5 days or less. However, there was considerable variation between the results obtained with the individual pesticides and species at other doses and temperatures. Reducing the temperature slowed the action of all the pesticides and was more apparent at the lower doses. Information was also collected on grain export procedures to allow the above data to be used to predict the success of treatments as vessels were loaded.

MANAGEMENT OF BRUCHIDS, THE MAJOR PEST OF STORED PULSES.

L.S. Sharma* Department of Entomology, Rajasthan Agriculture University, College of Agriculture, Udaipur 313 001 India.

The infestation of Pulse beetle *Callosobruchus maculatus* Fabr. (Coleoptera: Bruchidae) was found to the extent of 33.3 to 83.3 per cent in stored gram at Udaipur Division. The treatment of neem leaf powder, ash, sand and ash layer and insecticides such as BHC and Malathion at three doses viz., 10, 20 and 30 ppm were given to the stored gram and it was found that after 6 months malathion 30 ppm gave the maximum protection against bruchids showing the minimum infestation of 7.84 per cent, while in the treatment of 20 ppm malathion, the infestation of 16.87 per cent was observed which was comparatively lower than all other treatments including control. Malathion residues of 10.75 ppm from 30 ppm dose and 4.80 ppm from 20 ppm dose was detected in stored gram seeds, after six months.

THE INFLUENCE OF INSECT BEHAVIOUR ON THE PERFORMANCE OF RESIDUAL INSECTICIDES. D B Pinniger*, G Barson and K B Willey. ADAS, Slough Laboratory, London Road, Slough, Berks SL3 7HJ, UK.

The effectiveness of treatments with residual insecticides can be influenced more by the behaviour of the target insects and their response to the environment than the inherent toxicity of the active ingredient. Recent research has shown that activity, refuge-seeking and avoidance all contribute to the survival of some of the major beetle pests of stored products. Resistance to insecticides is an important component in the development of survival ability in these insects.

INSECTICIDE RESISTANCE AMONG FIELD STRAINS OF ALMOND MOTH AND INDIANMEAL MOTH (LEPIDOPTERA: PYRALIDAE) IN STORED PEANUTS. F. H. Arthur*, J. L. Zettler and W. R. Halliday, Stored-Product Insects Research and Development Laboratory, USDA-ARS, Savannah, GA 31403 USA.

Field strains of the almond moth *Cadra cautella* (Walker) and the Indianmeal moth *Plodia interpunctella* (Hübner) collected from peanut storage facilities were tested for resistance to dichlorvos, malathion, pirimiphos-methyl, chlorpyrifos-methyl and synergized pyrethrins. Evidence of dichlorvos resistance was present in 1 of 6 almond moth strains and all 16 Indianmeal moth strains tested. Malathion resistance was severe. The almond moth strain most resistant to dichlorvos was also resistant to pirimiphos-methyl and chlorpyrifos-methyl. One other almond moth strain showed resistance to chlorpyrifos-methyl. There were no clear indications of resistance in Indianmeal moth strains to pirimiphos-methyl or chlorpyrifos-methyl. Resistance to synergized pyrethrins was not severe. None of 7 almond moth strains and 20 Indianmeal moth strains tested had >5.4 fold resistance to synergized pyrethrins.

RELATIVE FITNESS OF MALATHION-RESISTANT GENOTYPES OF *CRYPTOLESTES FERRUGINEUS* (COLEOPTERA: CUCUJIDAE) WHEN DEVELOPMENT AND OVIPOSITION OCCUR IN MALATHION-TREATED AND UNTREATED WHEAT KERNELS. Noel D.G. White* and R.J. Bell, Agriculture Canada Research Station, 195 Dafoe Road, Winnipeg, Manitoba, Canada, R3T 2M9.

Developmental periods, oviposition and mortality for *Cryptolestes ferrugineus* that were malathion-specific resistant (RR) or susceptible (SS) strains and their reciprocal hybrids (RS) were determined in the germ of individual wheat kernels treated with 0, 4, 8, and 16 ppm malathion. Malathion treatments did not increase developmental time for the RR or the RS strains but offspring declined. Hybrid beetles (RS) developed two days faster than RR strain beetles at all malathion treatments and produced 25% more offspring at 0, 4, and 8 ppm malathion; at 16 ppm RS hybrids had fewer offspring and higher mortality than the RR strain. Both the RR and RS strains had similar intrinsic rates of increase at 16 ppm malathion. Reproductive fitness was compared among RR, RS and SS strains, and between RR and SS strains with genetic backgrounds made similar by backcrossing the heterozygote to the SS strain for 6 generations and reselection to homozygosity for malathion resistance. The R gene had no effect on fitness.

PERFORMANCE AND GROWER ACCEPTANCE OF PITFALL TRAPS USED TO MONITOR COLEOPTERA THAT INFEST FARM-STORED CORN IN NORTHEASTERN NORTH CAROLINA. R. C. Hillmann, Department of Entomology, Box 7613, North Carolina State University, Raleigh, North Carolina 27695-7613, USA.

Commercially available pitfall traps baited with an experimental aggregation pheromone, Sitophinone, captured from 2 to 6 times more *Sitophilus*, *Tribolium*, and *Cryptolestes* in farm bins of stored corn than did similar traps without this pheromone. All traps, baited or not, detected pest insects earlier than did samples taken with a 6-ft (1.8 m) compartmentalized grain trier. Indianmeal moth larvae invaded those traps placed near the grain surface necessitating placement to at least arm's length beneath grain surface to prevent webbing and subsequent clogging of the traps.

While growers were generally pleased with the traps, most said they would pay only \$5 to \$10 for one which is about half the customary retail cost.

RAPID DETECTION OF STORED PRODUCT INSECTS BY NON-TRAPPING METHODS. J. Chambers and D.R. Wilkin*, ADAS Slough Laboratory, London Road, Slough, Berks, SL3 7HJ, England.

Recent research on the detection of beetle pests of stored products has been largely focussed on the use of traps, sometimes augmented with chemical attractants. However good these methods can be made, there will always be some circumstances under which the use of traps is inappropriate. They cannot be used when an assessment is required rapidly, as is often the case for a load in transit arriving at a store, neither can they be effective in trapping immature stages of those pests such as the grain weevil which develop within the cereal grains, nor when the mobility of the pests is restricted by low temperatures. This paper defines the requirements for a new rapid detection method, reviews the presently known methods for the detection of hidden infestations and discusses recent research at Slough on completely new techniques which might solve the problem.

THE ROLE OF CONSPECIFIC SURFACE LIPIDS IN AGGREGATION OF YELLOW MEALWORMS, TENEBRIO MOLITOR L. (COLEOPTERA: TENEBRIONIDAE) LARVAE. David K. Weaver* and J.E. McFarlane, Department of Entomology, Macdonald College of McGill University, Ste. Anne de Bellevue, Quebec, Canada H9X 1C0.

Surface lipid extracts of larval and adult Tenebrio molitor were evaluated for both individual and grouped larval attractancy. The effects of varying concentrations and specific fractions were investigated. Significant differences in response were obtained using these criteria. The possible role of surface lipids in certain other types of larval Tenebrio molitor aggregation is discussed.

ON STORED PRODUCT MITES IN BRASIL (Acari).

C.H.W. Flechtman, Department of Zoology, ESALQ University of São Paulo, 13.400 Piracicaba, SP.

Microscopic examinations of various cereal samples (rice, beans, wheat, corn, oats, peas and sorghum), collected from large distributors and acquired at many small retailers, realized upon receipt and after 42 days incubation at 25°C and 70% RH showed that 49% of the samples presented primary stored food mites. Species present were Tyrophagus putrescentiae (Schrank), Aleuroglyphus ovatus (Troupeau), Glycyphagus domesticus (De Geer), Chortoglyphus arcuatus (Troupeau), Suidasia pontifica Oudemans, Blomia tropicalis Bronswicjk, Cock & Oshima.

Samples originating from the large distributors, when infested, where so in a much lower level than those from small retailers where cereals remain over longer periods before they are sold out and replaced.

The presence of mites in samples after 42 days of incubation when their examination upon receipt was negative for the these pests does not preclude the presence of mite eggs.

So far mites of the genus Acarus have not yet been found in Brazil.

TECHNIQUES FOR THE ISOLATION, IDENTIFICATION AND EVALUATION OF INSECT AND FOOD VOLATILES. J. Chambers† and P R White*. †ADAS Slough Laboratory, London Road, Slough Berks SL3 7HJ, England. *Dept of Entomology, 201 Welman Hall, U C Berkeley, CA94720.

The recent rapid growth in the number of chemicals which have been suggested for use in traps to augment the catch of stored product pests has to a large extent been dependent on the introduction of new, sometimes highly sophisticated, techniques. New techniques have an important role to play whether the problem is one of isolating useful volatiles from insects or foodstuffs selectively and efficiently, identifying which components are biologically active, characterising the chemical structure or defining the exact nature of the behavioural response. This paper will review a range of techniques which have been used in studies on several species of stored product beetle at Slough, assess their relative merits and discuss in particular the advances brought about by our ability to use EAG techniques with these species.

#100

STRATEGIES FOR CONTROL OF THE SMOKYBROWN COCKROACH, *PERIPLANETA FULIGINOSA* (SERVILLE): A HOUSE CASE STUDY. E.P. Benson* and P.A. Zungoli, Department of Entomology, Clemson University, Clemson, South Carolina, United States 29634-0365.

A home in Clemson, South Carolina, USA, with a large infestation of *P. fuliginosa* was monitored for approximately three years. During this time various strategies for control were implemented. For the first year of the study, population reduction was attempted by live trapping and removal of cockroaches from the premises. This resulted in no appreciable cockroach reduction. During year two, a single thorough indoor treatment with insecticides was used. Initially, this resulted in good control. However within the year, the cockroach population rose to pretreatment levels. For year three, an initial thorough insecticide treatment, both indoors and outdoors, along with physical habitat modification, scheduled monitoring and occasional spot treatments with insecticides resulted in excellent control.

#101

THE CHANGES OF THE STRUCTURE OF GRANARY BEETLES POPULATIONS AS A RESULT OF DENSITY AND TREATING GRAIN WITH THE EXTRACTS OF SEVERAL HERB SPECIES. Z. Ciesielska, Institute of Biology, Pedagogical University, Podbrzezcie 3, 31-054 Kraków, Poland.

This work is a continuation of the laboratory work concerning the relationship between the population structure, population dynamics and changes of sex ratio. The research dealt with the populations *Oryzaephilus surinamensis* L., *Rhizopertha dominica* F., *Sitophilus granarius* L. and *Sitophilus oryzae* L. in various environmental conditions such as initial density and treating grain with extracts present in several herb species. Extracts from *Salvia officinalis* L., *Melilotus officinalis* L., *Rhamnus frangula* L. and *Artemisia absyntium* L. were used. In the control experiments grain was soaked with water. After 40-80 days sex ratio increases owing to the higher female mortality when the substrate is treated with the herbal extracts, except *Salvia officinalis*. Higher initial density does not influence the structure or dynamics populations if the amount of food is sufficient.

#102

THE ECONOMIC IMPORTANCE OF SOME LESSER KNOWN INSECTS INCLUDING *Liposcelis divinatorius* (Muller) (PSOCOPTERA: LIPOCELIDAE) and various *Lathridius* species (COLEOPTERA: LATHRIDIIAE) P.T. Copps, PCO Services Limited Toronto, Ontario M8Z 2R4

Specimens of the booklouse *Liposcelis divinatorius* and minute brown scavenger beetles *Lathridius* Spp. were found in food plants and packaging manufacturing facilities located in eastern North America.

Economic losses were noted as a result of the presence of these and related insects.

An attempt was made to develop a pest management program. Efforts were hampered by a lack of information on the biology and habits of these insect.

#103

POPULATION ECOLOGY OF *TRIBOLIUM FREEMANI* HINTON (COLEOPTERA: TENEBRIONIDAE). O. Imura* and H. Nakakita, National Food Research Institute, Kannondai, Tsukuba 305, Japan.

This study aims at elucidating population ecology, with particular reference to population regulation, of *T. freemani*, a potential pest of stored products, under laboratory conditions. The studies of long-term population dynamics showed that the beetle maintained fairly low and stable population densities, although it had a λ of 8.9 per 30 days (Imura, 1987). Crowded conditions retarded pupation (Nakakita, 1982). A slight medium conditioning reduced the egg production significantly. Eggs, pupae and callow adults were eaten voraciously by larvae and adults, resulting in high mortalities of these stages. Female adults were more voracious than males and 8-10 days old larvae were the most effective predator on eggs. The estimated mortality of egg stage was 81% and that of pupal stage including callow adults was 96%. In addition to the sensitive responses to overcrowding, those strong cannibalistic habits of the beetle were considered to be main factors which determined the population density of *T. freemani*.

#104

STUDIES ON THE INHIBITION OF PUPATION UNDER CROWDED CONDITION IN *TRIBOLIUM FREEMANI* HINTON (COLEOPTERA: TENEBRIONIDAE). T. Kotaki* and H. Nakakita, Stored-Product Entomology Laboratory, National Food Research Institute, Tsukuba, Ibaraki 305, Japan.

In *Tribolium freemani*, a sibling species of *T. castaneum*, pupation was greatly inhibited by crowding effect which induced supernumerary moulting without enlargement of body size. The inhibition was easily terminated when the larvae were isolated or less crowded. These phenomena might imply that under crowded condition, JH titer in the hemolymph is enough high to persist in larval stage. To elucidate the mechanism, we examined the larvae with several chemicals having hormonal activities; JH, JHA and AJHA. Topical application of JH I and two JHA, methoprene and S-31183, prevented pupation of the larvae and induced stationary larval moulting in the similar manner to that observed under crowded condition. Dose of AJHA, either of Precocene I or II, mixed with diet effectively terminated the inhibition of pupation caused by crowding. In addition, dose of JHA with precocene weakened the "Precocene effect" on pupation, which seems to be the "rescue effect".

#105

A THERMAL TREATMENT TO ERADICATE INSECTS FROM INFESTED WHEAT. H.M. Lapp*, F.J. Madrid, Retired Professor of Agricultural Engineering and Department of Food Science respectively, University of Manitoba, Winnipeg, Manitoba, R3T 2N2

Insects are killed when they are exposed to a temperature ranging from 50 to 56°C during a residence interval of 2 minutes in the treatment process. A direct exposure of insects to the temperature range for 20 seconds is adequate to cause their demise in all stages of their life cycle (egg, larvae, pupa and adult). There was no deterioration in the germination or milling quality of wheat as a result of the process. A clear reduction in the presence of micro flora was observed in alternaria infection and especially in the aspergillus glaucus group.

#106

INVESTIGATION OF THE RADIATION EFFECTS ON THE EPICUTICULAR HYDROCARBONS OF GRANARY WEEVIL, SITOPHILUS GRANARIUS (L.) (STORED-PRODUCT INSECT, COLEOPTERA:CURCULIONIDAE). Shobha Sriharan^{1*}, T.P. Sriharan², Susan Sellers³, Wolfgang Bertsch⁴ and R.S. Saini⁵. ^{1,2}Selma University, Selma, AL 36701, ^{3,4}The University of Alabama, University, AL and ⁵Tuskegee University, Tuskegee, AL, all in the USA.

Epicuticular hydrocarbons play an important role in preventing dessication. The use of gamma radiation for the disinfection of stored-product commodities has been recommended which encouraged this study.

Adult weevils of different age groups of Sitophilus granarius (L.) were exposed to gamma radiation (cesium¹³⁷) of dose rates, 0.10KGy, 0.15KGy and 0.30KGy and confined on wheat under constant temperature and humidity. Weevils of different age groups were used in this study. The epicuticular hydrocarbons of treated and control weevils were extracted and analyzed by gas chromatography-mass spectrometry (GC/MS).

The results showed that there were qualitative and significant quantitative differences in the hydrocarbons of C₂₃ to C₃₅ in the treated and untreated groups. Variations were also noticed between the treated groups. (Department of Energy Grant No. LE-FG02-86CH10288.A001).

#107

GALIC AS AN ATTRACTANT FOR AND A PESTICIDE AGAINST STORED-PRODUCT PESTS. T. Yoshida, Laboratory of Applied Entomology, College of Agriculture, Okayama University, Okayama 700, Japan.

In Japan, farmers traditionally use galic as a pesticide especially against Sitophilus zeamais. But until now its effectiveness was unknown. The efficacy of galic as an attractant for and a pesticide against stored product pests was ascertained.

<As Attractant> Galic was found effective as an attractant for Sitophilus zeamais and Sitophilus oryzae.

<As Pesticide> Galic has been tested for pesticide property against Sitophilus zeamais, Sitophilus oryzae, Callosobruchus chinensis, Callosobruchus maculatus, Tribolium castaneum and Tribolium confusum. The results showed that galic effectively protect grains, beans or flour from damage by Sitophilus zeamais and Callosobruchus spp., but ineffectively by Sitophilus oryzae and Tribolium spp.

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ANTENNA AND ANTENAL SENSILLA DIMORPHISM IN CALLOSBRUCHUS CHINENSIS L. (COLEOPTERA:BRUCHIDAE). P.J. Rup, Department of Biology, Guru Nanak Dev University, Amritsar-143005, India.

The new biotechnical approaches to stored grain pest control depend upon the use of insectistics. The pheromonal manipulations make significant contributions in these technical approaches. The knowledge about the pheromone producing organs, receptor sites, chemical nature and related behaviour is essential for the manipulation of pheromones as insectistics against any species. The presence of female sex pheromone in Callosobruchus chinensis L., a pest of pulses in storage has been demonstrated. The morphological studies on the antenna of C. chinensis showed that although the number of annuli in both the sexes was same, the ratio of antennal length to body was 4:3 in male and 2:1 in female and the pectens in male were very large. Scanning under dark field with polarized light revealed the presence of three types of sensilla (trichodea_{TT}, trichodea_{II} and basiconia) in both the sexes. The number of sensilla trichodea_{TT} and basiconia decreased from distal to proximal annulus and were radially arranged on the annuli. Further the size and number of sensilla trichodea_{TT} were significantly more in males (910/antenna) as compared to females (680/antenna) thereby suggesting a possible sex pheromone detection role.

Recent Advances In Research On The Mechanisms And Management Of Insecticide Resistance In Insects

TOXICOKINETIC EVALUATION OF VARIOUS FACTORS AND THEIR INTERACTION FOR DIAZINON RESISTANCE IN THE HOUSEFLY. N. Motoyama* and M. Oi, Faculty of Horticulture, Chiba University, Matsudo, Chiba-ken 271, Japan.

The paper deals with toxicokinetic analyses to evaluate the *in vivo* significance of various resistance factors. Following topical application or injection of diazinon and diazoxon at different doses, their fate and effect on AChE were investigated in progress of time. Based on the data, various models were devised to describe the event and simulated using a computer. Rate constants for penetration, activation, and degradation of diazinon as well as for AChE inhibition were also determined by computer simulation. Among all the factors contributing to diazinon resistance, reduced activation, increased degradation of diazoxon, and insensitivity of AChE were the most important. The presence of a monooxygenase system with higher affinity for degradation than activation of diazinon especially at high doses was implicated in the resistant strain.

ADVANCES IN RESEARCH ON MECHANISMS OF RESISTANCE TO PYRETHROID INSECTICIDES. J.G. Scott, Department of Entomology, Comstock Hall, Cornell University, Ithaca, NY 14853, U.S.A.

Over the last ten years, the pyrethroid insecticides have emerged to become one of the most widely used classes of insecticides. Unfortunately, resistance to pyrethroids has already been detected in several pest species. Clearly, an understanding of the mechanisms involved in resistance will be a key in developing strategies to overcome or slow the development of resistance. Currently, four mechanisms of resistance to pyrethroid insecticides have been found: 1) Mixed function oxidase (MFO) mediated detoxication, 2) nervous system insensitivity (*kdr*), esterase mediated detoxication and storage. MFO and *kdr* are the two major mechanisms of resistance. MFO mediated resistance appears to be due to elevated levels of one or more of the components of the MFO cycle: Cytochrome P-450, P-450 reductase and/or cytochrome b_5 . The molecular nature of the *kdr* mechanism is not completely understood, but may represent an altered form of the sodium channel or neural membrane.

MAJOR ROLE FOR A REGULATORY GENE IN METABOLIC RESISTANCE TO INSECTICIDES IN THE HOUSE FLY *MUSCA DOMESTICA* L (DIPTERA: MUSCIDAE). F. W. Plapp, Jr., Entomology Department, Texas A&M University, College Station, TX 77843, U.S.A.

In the house fly metabolic resistance to insecticides is almost always under the control of a major gene on chromosome II. Usually, there is interaction between this gene and genes on other chromosomes. Evidence will be presented showing that the protein product of the major gene on chromosome II is a high affinity juvenile hormone binding protein, most probably a juvenile hormone receptor, which recognizes and binds insecticides. The result of the binding is the induction of synthesis of specific detoxifying enzymes. Genetic and biochemical evidence on the events associated with the process of xenobiotic recognition and enzyme induction in relation to resistance will be described.

THE EVOLUTION OF RESISTANCE GENES IN *CULEX PIPPIENS* IN FRANCE UNDER PROLONGED ORGANOPHOSPHATE SELECTION PRESSURE. N. Pasteur*, M. Raymond and E. Marboutin, CNRS/LA327, Université de Montpellier II, 34060 Montpellier, France.

Culex pipiens populations in southern France have been controlled with the organophosphate (OP) insecticide chlorpyrifos (CHL) since 1968. When resistance was first detected in 1972, it was restricted to a single village. By 1974, it had spread throughout and beyond the controlled area. This resistance was due to a single gene coding for the detoxifying esterase A1 (resistance ratio [RR] = 5-10-fold). A sharp increase in RR was noted in 1978, due to the selection of a gene coding for an insensitive acetylcholinesterase (AChE) (RR = 100-fold to CHL, and 10,000 to propoxur). A field study of over 100 populations, conducted in 1986-87, disclosed that the frequencies of these two genes are high (80-100%) and strongly correlated in the treated zone; they decline slowly, reaching 2-5% 200 km west and north of this zone. Two other detoxifying esterases with increased activity were also found. One is present in 5-10% of the insects in all populations, the other was found only in a very restricted area. Thus, prolonged selection with OPs has successively selected several resistance genes. Unexpectedly, the more recently selected genes provide less efficient protection than the insensitive AChE. Interpreting these results requires a good knowledge on the genetic exchanges between populations and on the physiological and genetic interactions between the different resistance genes.

THE EMERGENCE AND CHARACTERIZATION OF RESISTANCE GENES IN THE SHEEP BLOWFLY UNDER FIELD AND LABORATORY SELECTION P.B. Hughes*, Department of Agriculture, New South Wales, P.M.B. 10, Rydalmere, N.S.W. 2116, Australia.

The sheep blowfly, *Lucilia cuprina* (Wiedemann) (Diptera: Calliphoridae), has evolved at least 3 major resistance genes over a 40 year period of field selection. Additional genes have been identified which influence both resistance mechanisms and biotic fitness in resistant insects. Non-specific organophosphorus (OP) resistance is due to the gene *Rop-1* (chromosome 4) which controls a detoxifying esterase analogous to the "mutant ali-esterase" found in OP resistant houseflies. The effect of *Rop-1* is significantly enhanced by additional genes (chromosome 6) initiating increased mixed-function oxidase activity. These additional genes become especially significant to carbamate resistance and can be rapidly selected. The genetic basis of these resistances is complicated further by differences between the adult and larval stages. Similar genetic interaction results in pyrethroid resistance induced by laboratory selection. The history of resistance in the sheep blowfly will be discussed in terms of the factors that have influenced its evolution.

ADVANCES IN MOLECULAR GENETICS OF ORGANOPHOSPHATE-DETOXIFYING ESTERASES IN INSECTS. C. Mouchès*, N. Pasteur, L. Lemieux, Y. Poplin, M. Abadon and G.P. Georgiou. INRA, B.P. 2078, 06606-ANTIBES & USTL, 34060 MONTPELLIER (FRANCE); U.C. RIVERSIDE, CA 92521 (USA).

The DNA structure responsible for overproduction of esterase B1 in organophosphate (o.p.)-resistant *Culex quinquefasciatus* (Science, 233, 778-780) consists of about 250 copies of a constant 22 Kb "core amplification unit". Genomic mapping experiments indicate that all the cores are amplified at a unique sector of the genome. DNA sequences on the side of the various cores are heterogeneous in their structure, probably as a result of rearrangements that have occurred in these areas during the amplification process. They contain some of the sequences of the core rearranged with other sequences repeated to a lower frequency than the core's DNA.

The esterase gene takes up less than 3 Kb of the core. It contains several introns and a sequence encoding the characteristic consensus polypeptide shared at their active site by eucaryotic serine-esterases. Most of the DNA sequences coamplified with the gene are amplified only in mosquitoes overproducing esterase B and not in the genome of o.p.-susceptible insects. However, two repetitive DNA sequences dispersed in the genome of both o.p.-resistant and susceptible mosquitoes are coamplified with the o.p.-selected esterase B1 gene. These findings suggest that insecticides can be responsible for the dispersion and spreading of mobile genetic elements such as transposons in natural populations.

ADVANCES IN MOLECULAR GENETICS OF ACETYLCHOLINESTERASE INSENSITIVITY IN INSECTICIDE-RESISTANT INSECTS. J.B. Bergé* and D. Fournier, Station de Nématologie, Centre de Recherches d'Antibes, 06606 Antibes, France.

Acetylcholinesterase (AChE) is a very important enzyme, carrying out an important physiological function in the cholinergic synapses of the nervous system. The structure of this protein, in insects, has been recently elucidated. There are various native isozymes, but the basic native unit is a 75 kDa protein which can be dimerized by a disulfide bridge to form a 150 kDa protein. Each of the soluble forms can be found also as an amphiphilic protein in which the polypeptide is linked to a glycolipidic tail, anchoring AChE in membranes and giving to the peptide a very strong hydrophobic character.

The peptidic composition of the active unit has been investigated using ^3H diisopropylfluorophosphate, disulfide bridge reduction and SDS PAGE. The active subunit is made of two peptides of which the MW has been estimated electrophoretically to be 55 and 18 kDa. These peptides are not covalently associated. The serine of the esterase subsite is on the 55 kDa peptide. These features are similar for the sensitive and resistant AChE, hence these proteins cannot be differentiated by physico-chemical parameters, except for their affinity for insecticides.

The structure of the ace gene encoding AChE has been investigated in *Drosophila melanogaster*. It has been shown that the ace genomic DNA is spread over 30 kb on the third chromosome. The insect ace gene bears 10 exons and is, in that respect, more complicated than the vertebrate gene.

Comparison of the coding sequences of the DNA from susceptible and resistant *D. melanogaster* strains shows two kinds of mutations. Some which do not correspond to a variation in the amino acid sequence of the protein, are silent. We have only noticed one significant mutation between resistant ace (ace^1) and the sensitive one (ace^2). It involves the replacement of a phenylalanine by a tyrosine in the resistant strain DNA. Data obtained from the vertebrate and invertebrate AChE, as well as vertebrate butyrylcholinesterases sequences, show that this phenylalanine is a highly conserved amino acid.

We have finally investigated methods to obtain either genes encoding a very resistant AChE or insecticides adapted to naturally resistant AChE.

DETECTION AND MONITORING OF INSECTICIDE RESISTANCE IN AGRICULTURAL INSECT PESTS. T. Miyata, Laboratory of Applied Entomology and Nematology, Faculty of Agriculture, Nagoya University, Chikusa, Nagoya, 464 Japan.

The number of species of Arthropoda with reported cases of resistance to insecticides exceeded 400. The mere number of resistant Arthropoda does not adequately reflect the present status of insecticide resistance. Besides cross-resistance or multiple-resistance and geographical distribution of resistant populations should be considered. Management of insecticide resistance has become a very important subject. For management of insecticide resistance, efficient methods to detect resistance in the early stage of development. Biochemical monitoring methods are useful for detecting resistance. These methods can detect resistance at the early stage of development when gene frequency for resistance is very low. However, we sometimes cannot expect resistance level or kind of insecticides which Arthropoda show resistance by biochemical methods. In such cases, efficient and simple bioassay methods such as rapid susceptibility tests in the field or tests with a discriminating dosage are useful.

IMMUNOLOGICAL MONITORING OF INSECTICIDE RESISTANCE IN *MYZUS PERSICAE* POPULATIONS. R.H. French-Constant* and A.L. Devonshire, Rothamsted Experimental Station, Harpenden, Herts. AL5 2JQ, England.

The use of an immunoassay for esterase-4 (E4) for monitoring insecticide resistance in *Myzus persicae* populations in England is described. This assay was used to study the rate and pattern of selection exerted by different classes of insecticides on known resistance variants in field cages and on native populations in the open field in the presence of immigration. A carbamate insecticide was shown to select less strongly and give better control than an organophosphorus (OP) insecticide or a pyrethroid/OP mixture. Pyrethroid treatments selected strongly for resistance and increased aphid populations. Detailed studies were complemented by field surveys of untreated and treated crops. These showed the appearance of extreme levels of resistance in the field. The consequences of the widespread appearance of these extremely resistant aphids for monitoring and control are discussed.

NOVEL TESTS FOR DETECTION OF RESISTANCE MECHANISMS IN SINGLE INSECTS. G. P. Georgioui, Department of Entomology, University of California, Riverside, California, 92521, USA.

Biochemical diagnostic tests suitable for detection of nonspecific organophosphate (OP) detoxifying esterases or insensitive acetylcholinesterase (AChE) in single mosquitoes were developed and tested for monitoring OP resistance. Esterases were detected enzymatically and immunologically in *Culex quinquefasciatus* and *C. pipiens*. Enzymatic methods consist of an improved filter paper test (FP/Est test) and a microtitre plate test (MT/Est test). Both methods are based on the production of α -naphthol stained with Fast Garnett. They are essentially qualitative, detecting the presence of esterase and of resistance. However, quantification is also feasible, especially in the MT/Est test, through comparison of staining intensity against that obtained with serial dilution of naphthol. Immunological assays are based on dot-blot or ELISA methods using antibodies prepared against esterase B1. Detection of insensitive AChE in *Culex* and *Anopheles* was accomplished on nitrocellulose membranes (NC/AChE test) or in microtitre plates (MT/AChE test). In NC/AChE tests, aliquots of each mosquito homogenate are deposited on several filters. Insensitive AChE is identified by comparing the staining intensity of homogenates on filters that are incubated in the presence or absence of insecticide and subsequently developed by the Karnovsky and Roots staining technique utilizing acetylthiocholine iodide. 28 collections of *Culex* from the US and abroad were tested for OP resistance using the esterase tests, electrophoresis, and bioassays with temephos, chlorpyrifos, fenitrothion and malathion. Satisfactory correlations were obtained with all insecticides except malathion.

THE ROLE OF BIOTIC FITNESS IN THE PERSISTENCE OF INSECTICIDE RESISTANCE. J. Keiding, Danish Pest Infestation Laboratory, Skovbrynet 14, DK-2800 Lyngby, Denmark.

Common sense and mathematical models indicate that the biotic fitness of resistant versus susceptible geno- and pheno-types plays an important role in the development and persistence of insecticide resistance. In the laboratory experiments, fitness-parameters such as rate of development and reproduction, longevity, etc. may be measured, or fitness may be determined by following the frequency of resistant phenotypes in laboratory colonies. However, such investigations are done under more or less artificial conditions. Therefore, the main emphasis will be put on investigations of resistance in natural populations of insects, the development in relation to selection pressure with insecticides and the persistence when the selection pressure is relaxed. This is illustrated by own data from longterm monitoring of resistance in housefly populations on Danish farms to organophosphorus compounds and pyrethroids. The role of co-adaptation (development of biotic fitness) of resistant strains will especially be discussed.

Recent Advances In Research On The Mechanisms And Management Of Insecticide Resistance In Insects

APPLICATION OF TECHNIQUES OF ARTIFICIAL INTELLIGENCE TOWARD MANAGEMENT OF INSECTICIDE RESISTANCE. C.E. Taylor, University of California, Los Angeles, CA.

Our objective has been to develop better ways of using insecticides, so that pests are controlled but resistance does not develop, or at least does so more slowly. We have developed a simulation system, RAM, that is able to capture many of the human and ecological interactions involved with mosquito control. MAD personnel are represented by separate data objects, and so are the mosquito populations that live in different locations and substrates. Each such object is endowed with its own program, complete with memory, behavior, and genotype. Just as real animals are born, live, interact, reproduce with modification, and die, so too can these programs initiate, execute, learn, communicate, replicate with modification, and terminate. They are capable of the full range of interactions that need to be modeled. The program object for the supervisor, with which one can study alternative control rules, is an expert system designed according to the usual methods of artificial intelligence. Different rules that might be used for control can then be evaluated for their ability to control mosquito populations and for the effect they have on the development of resistance.

MANAGEMENT OF INSECTICIDE RESISTANCE IN THE TROPICS. T.Saito*, Faculty of Agriculture, Nagoya University, Chikusa, Nagoya, 464 Japan and N.Sinchaisri, Department of Entomology, Kasetsart University, Bangkok 10900, Thailand.

In recent years, many insecticide resistance problems occurred in not only developed countries but also developing countries, because the introduction of the new crop varieties and irrigation system which were all the year cultivations resulted increases insect pest attacks and required increased insecticide application. Strategies to avoid or delay the development of resistance in the target pest are most important in tropics. We have many concepts and suggestions of measures to overcome resistance in insect pests. Basic resistance research in genetics, biochemistry, physiology, and toxicology on tropical insects is needed. Improved monitoring techniques for the population density and detecting of resistance are needed. Precise timing of insecticide application, based of field scouting data, crop rotation, cultural practices, and resistant cultivar are effective on management of insecticide resistance in the tropics.

RESISTANCE MANAGEMENT OF THE TWOSPOTTED SPIDER MITE (*TETRANYCHUS URTICAE* KOCH) IN TREE FRUIT. J.L. Flexner* and B.A. Croft, Department of Entomology, Oregon State University, Corvallis OR, USA 97331-2907.

Recently, resistance to the organotin (OT's) has been documented in the twospotted spider mite. In Australia and the United States this resistance is unstable and mites will revert back to susceptible (in the laboratory) when OT selection pressure is relaxed. This reversion has been shown to be due to a reproductive disadvantage of the resistant genotypes. Field resistant mites had longer developmental times and lower percent survival (egg to adult) than field susceptible strains. In the field, OT efficacy was significantly improved when selection pressure to a population of *T. urticae* from southern Oregon pear was reduced by substitution of an acaricide to which the mites were not cross resistant. After two years of relaxed selection a standard OT treatment was reapplied to this block and significantly better control was achieved compared to a block that had received continuous OT treatments. These results suggest a possible mechanism by which OT resistance in *T. urticae* may be managed.

MANAGEMENT OF INSECTICIDE RESISTANCE IN *PLUTELLA XYLOSTELLA* (L.) (LEPIDOPTERA: PLUTELLIDAE). C. N. Sun* and C. F. Hung, Department of Entomology, National Chung-Hsing University, Taichung, Taiwan 40227, Republic of China

Diamondback moth, an insect of cruciferous crops, has become resistant to all major groups of synthetic insecticides. Reduced sensitivity of the acetylcholinesterase contributed in part to the resistance to some organophosphorus insecticides. Enhanced microsomal oxidation was closely related to resistance to both pyrethroids and some chitin synthesis inhibitors. However, a lack of cross resistance between these two groups of compounds suggested that different microsomal oxidases might be involved. Resistance to some organophosphorus insecticides and chitin synthesis inhibitors, and pyrethroid/synergist mixtures were relatively unstable while resistance to pyrethroids was quite persistent. Based on known resistance mechanisms and the stability of resistance in this insect, recommendations are made regarding the use of synergists which inhibit microsomal oxidation, pyrethroids, organophosphorus insecticides and chitin synthesis inhibitors.

ADVANCES IN RESEARCH ON GENETICS, MECHANISMS, AND POTENTIAL FOR MANAGEMENT OF RESISTANCE IN THE COLORADO POTATO BEETLE. R.T. Roush, Department of Entomology, Comstock Hall, Cornell University, Ithaca, New York 14853, USA

Research on the genetics and mechanisms of resistance in Colorado potato beetle (CPB) will be critically reviewed. An update will also be given on the status of resistance across the USA. As has been well documented in the literature, CPB from Long Island, New York are highly resistant to virtually all modern organic pesticides. Recent monitoring results, however, show that resistance is even worse in several inland areas. These results will be discussed in the context of the ecological and genetic factors that promote the evolution of resistance in CPB. Selection for resistance (discrimination between resistant and susceptible genotypes) seems to occur across all larval instars in addition to the adults or a few instars. This provides at least a partial explanation for the rapid rate of selection for resistance in CPB compared to most other pests. Pesticide mixtures, particularly in combination with crop rotation, might be a viable option for resistance management.

STATUS OF PYRETHROID RESISTANCE IN *HELIOTHIS ARMIGERA* (LEPIDOPTERA: NOCTUIDAE) AFTER FOUR YEARS OF MANAGEMENT: THE AUSTRALIAN EXPERIENCE. Joanne C. Daly, CSIRO Division of Entomology, Canberra, ACT, Australia.

A voluntary insecticide resistance management (IRM) strategy was rapidly implemented in eastern inland Australia after an outbreak of pyrethroid resistance in *H. armigera* in 1983. Since then, synthetic pyrethroids have been used successfully for *H. armigera* control during a specified six weeks in summer, although some problems have been noted in recent years. In the absence of data about the details of either the biology of *H. armigera*, or of the biology of resistance, the IRM strategy was based on theoretical models. Since its implementation the strategy has been supported by monitoring programs and by research both into the evolutionary biology and mechanisms of resistance, and into the population structure of *H. armigera*. The Australian research has shown that at least two, and possibly three, major genes have contributed to pyrethroid resistance, resistant individuals do not appear to be less fit in the absence of insecticide, the dominance of at least one of the resistance genes varies depending on genetic background and on the age of the larvae and immigration of susceptible insects into sprayed areas is probably important in the dilution of resistance in sprayed areas.

ACTIVITIES BY THE IOBC/WPRS WORKING GROUP "PESTICIDES AND BENEFICIAL ORGANISMS" TO TEST THE SIDE EFFECTS OF PESTICIDES: S.A. Hassan, Institute for Biological Pest Control, Heinrichstr. 243, D-6100 Darmstadt, Germany, Fed. Rep.

The Working Group "Pesticides and Beneficial Organisms" of the International Organization for Biological Control (IOBC), West Palaearctic Regional Section (WPRS) was formed in 1974. Standard laboratory, semi-field and field testing methods were developed and joint pesticide testing programmes were carried out. Special attention in the last few years was given to compare results obtained from laboratory, semi-field and field experiments. Additional laboratory methods to test the side effects on more protected life stages of arthropods (parasites within their hosts and adults of predators) are being developed at the present time. Laboratory methods were developed for 19 different beneficial arthropods, 1 entomopathogenic fungus, semi-field methods for 8 arthropods and field methods for 2 arthropods. Field tests to assess the effects on the arthropod fauna of apple orchards and arable crops were also developed.

WHAT A PESTICIDE MANUFACTURER NEEDS TO KNOW ABOUT NON-TARGET TERRESTRIAL ARTHROPODS. R.A. Brown, Ecology & Soil Science Section, ICI Agrochemicals, Jealotts Hill Research Station, Bracknell, Berkshire, RG12 6EY. UK

A pesticide manufacturer must take decisions during the development of a new pesticide about whether its impact on non-target insects is acceptable. In some cases, such as with pollinators, the criteria for these are reasonably well defined, though there are considerable differences of approach in different countries. In other cases, such as with parasites and in particular predators, there is little agreement as to what is acceptable and even less so with non-pest prey species. From this basis of uncertainty, the manufacturer has to formulate a policy of the acceptability of impacts on non-target arthropods. An approach currently being investigated with a broad spectrum pyrethroid insecticide, lambda-cyhalothrin, is discussed.

THE DESIGN OF EXPERIMENTS TO ASSESS THE EFFECTS OF PESTICIDES ON BENEFICIAL ARTHROPODS IN ORCHARDS: REPLICATION VERSUS PLOT SIZE. K.C. Brown, Shell Research Ltd., Sittingbourne Research Centre, Sittingbourne, Kent, ME9 8AG, England.

This paper presents the methodology and design used to investigate the effects of the insect growth regulant, flufenoxuron, on the beneficial fauna of orchards. During 1987 two field experiments were carried out in adjacent blocks of apples in southern France to investigate the effects of flufenoxuron on predatory and parasitic insects. A small plot replicated experiment (30 trees/plot) was established in one half of a large abandoned orchard (1170 trees). In this experiment a D-vac suction sampler (modified with a narrow nozzle) was used to sample predatory Heteroptera, Coccinellidae, and Chrysopidae. The provision of cardboard refuges on branches proved an effective method of sampling earwigs. Phytophagous mites were sampled by visual observation of leaves. A large plot unreplicated study (150 trees/plot) was established at the same time in the other half of the orchard. The beneficial fauna in this experiment were sampled using an inventory spray with dichlorvos. Inventory sampled trees had cotton sheets pegged beneath them to collect falling specimens. Water traps were used to sample alate species, particularly Diptera and Hymenoptera. Phytophagous mites were also sampled by visual observation. The relative benefits and limitations of each sampling method are discussed together with the suitability of each experimental design for the assessment of effects of insect growth regulants.

THE POPULATION ECOLOGY OF PEST-PESTICIDE-NATURAL ENEMY INTERACTIONS. Jeff Waage, CAB International Institute of Biological Control (CIBC), Silwood Park, Ascot, Berks UK SL5 7PY.

Natural enemies and pesticides act, and often interact, as mortality factors on the dynamics of many pest populations. Their potential to be complementary, antagonistic or even synergistic may depend not only on the toxic effects of pesticides on natural enemies, but the way in which pesticides affect pest populations and, indirectly, natural enemy behaviour.

MONITORING PESTICIDE SIDE-EFFECTS IN LARGE-SCALE TREATMENT PROGRAMMES: TSETSE SPRAYING IN AFRICA. I.F. Grant, Overseas Development Natural Resources Institute, College House, Wrights Lane, London W8 5SJ, U.K.

Modern chemical strategies for tsetse fly control in Africa draw on a combination of techniques: ground spraying, aerial spraying and, at the experimental level, the use of odour-baited targets. Dry season spraying of thousands of km² of semi-natural habitat is potentially hazardous to non-target organisms and ecological processes. The extent of environmental monitoring in terrestrial and aquatic habitats is dictated by limited financial resources, manpower, techniques and equipment, which is reflected in studies made to date. Methods for assessing the environmental impact of pesticides on tropical terrestrial and aquatic ecosystems are reviewed. Appropriate descriptive and functional approaches are discussed.

THE SPATIAL DYNAMICS OF PESTICIDE: NON-TARGET INVERTEBRATE INTERACTIONS. P.C. Jepson, Department of Biology, Medical and Biological Sciences Building, Bassett Crescent East, Southampton, SO9 3TU, UK.

The side-effects of pesticides on non-target invertebrates can be investigated on a variety of spatial scales. The choice of a particular scale will determine the nature of the questions that can be asked and will have important implications for appropriate methodology and the value of the data in determining the level and duration of the effect. All three scales (micro-, meso- and mega-) can make a contribution towards establishing the mechanism of an effect and providing a quantitative framework for systems analysis purposes.

Micro-scale investigations can quantify the relative exposure of different invertebrate guilds to pesticides within a treated area and determine the effects on individual organisms; meso-scale studies may then examine the implications of this exposure for population dynamics of exposed groups within a season and finally data obtained on the macro-scale may enable the long-term consequences of exposure and the recovery of communities to be studied. This framework is being used to investigate the effects of arable crop foliar sprays in the UK and to quantify the hazard to a range of non-target invertebrate guilds.

SUBLETHAL EFFECTS OF PESTICIDES ON BENEFICIAL PARASITOIDS. G. W. Elzen, U.S. Department of Agriculture, Agricultural Research Service, Southern Field Crop Insect Management Laboratory, Stoneville, Mississippi (USA) 38776.

Much research has been conducted on the effects of pesticides on beneficial insects, especially since release and resurgence of primary and secondary pests have been documented in some heavily sprayed monocultures. Actions of insecticides upon beneficial insects include not only those causing direct mortality, but also those that act in indirect ways, or that alter natural enemy biology unfavorably. The following questions concerning pesticide interactions with beneficial parasitoids are addressed: (1) What are the relationships among methods of assaying insecticide toxicity, and how do laboratory, spray tower, and field applications correlate to predict insecticide effects; (2) What are the consequences of sublethal effects on developing parasitoid populations; (3) What is the influence of sublethal doses of insecticides on beneficial parasitoid foraging, host habitat, and host location. Even if insecticides do not kill natural enemies, they may so affect them that normal behavior or reproduction is hindered or impossible.

SELECTIVE APPLICATION STRATEGIES OF INSECTICIDES IN AGRICULTURAL CROPS. H.M. Poehling, Institute of Phytomedicine, University of Hohenheim, Otto-Sander-Straße 5, 7000 Stuttgart 70, West Germany.

An important aim of modern pest control is the use of pesticides in a more selective way to reduce side-effects on non-target organisms. This is of economical as well as of ecological value. From the economical point of view, for example, protected predators and parasitoids of insect pests may be used as efficient long-term control agents leading to a reduction of the intensity of insecticide treatments and a better economic return of pesticides. On the other hand, pesticides with selective properties - evaluated experimentally only with a small number of selected test organisms (mainly economically important antagonists) - may be of lower toxicity to a wider range of insect species in the agroecosystem. The selection and application of selective pesticides is a first important step to reduce pesticide side-effects. However, it could be shown in different investigations during the last years that also selective preparations could have very detrimental effects on those beneficial or indifferent insect species which are strongly influenced in their population dynamics by fluctuations in pest abundance. These indirect effects can be avoided to a certain degree if the efficacy of insecticides for the pest species is reduced. This can be achieved in different ways which are to be reviewed and discussed here; the choice of slow acting substances, the use of reduced dose rates or altered application techniques leading to uncontaminated areas as refuge places.

FARMING PRACTICES TO REDUCE THE EXPOSURE OF NON-TARGET ARTHROPODS TO PESTICIDES. N.W. Sotherton, The Cereals and Gamebirds Research Project, The Game Conservancy, Fordingbridge, Hampshire, SP6 1EF, U.K.

Following the decline of a native species of gamebird, the grey partridge (*Perdix perdix* L.) in the U.K. cereal ecosystem, concern has been expressed over the exposure of beneficial, non-target arthropods to the increasingly intensive nature of cereal production, especially the associated use of pesticides. Pesticides are thought to be disrupting the arthropod items in the food chains of young, insectivorous chicks via the direct actions of insecticidal compounds and via the indirect action of herbicides acting upon the insect host plants.

Three methods are investigated to reduce the effects of pesticides on non-target arthropods:

1. The screening of compounds in both laboratory tests and field trials to assess the extent of any insecticidal activity against non-target invertebrates.
2. The selective use of pesticides on the outermost margins of cereal fields, the so-called "conservation headlands".
3. The enhancement of populations of insect pest natural enemies within integrated pest control programmes to avoid unnecessary use of insecticides and their resulting detrimental effects on game and wildlife.

TOXICITY, SELECTIVITY AND SUB-LETHAL EFFECTS OF PESTICIDES ON ARTHROPOD NATURAL ENEMIES: A DATABASE SUMMARY. K.M. Theiling and B.A. Croft, Dept. of Entomology, Oregon State University, Corvallis, Oregon, USA 97331

Documented side-effects of pesticides on arthropod natural enemies represent a massive information base which is difficult to summarize by empirical methods alone. Improved microcomputer technology and database management software allow rapid access, evaluation and integration of this information at a level which was not previously feasible. A database (SELCTV) of this information has been developed for characterization, analysis and use in decision-making for pest control and environmental impact assessment. Currently, the database holds some 12,600 records containing pesticide side-effects data for over 600 species of natural enemies and 400 agricultural chemicals. The largest and most detailed component of the database describes pesticide toxicity. Selectivity data make up a moderate component, but are somewhat biased by how the published literature are reported. Documented sub-lethal effects of pesticides are meager, but expanding rapidly. The linkage of SELCTV to existing pesticide databases is discussed, as well as its applicability to other activities such as standardized testing and decision-making in pest management. Both national and international applications of the database are being developed.

LONG-TERM EFFECTS OF PESTICIDES ON NATURAL ENEMIES OF CEREAL PESTS. A.J. Burn, Department of Applied Biology, University of Cambridge, Cambridge, U.K.

Between 1982 and 1988, MAFF have been carrying out a large-scale experiment into the effects of intensive pesticide use on the cereal ecosystem at Boxworth, in Cambridgeshire, U.K. A comparison is being made between a high pesticide input (Insurance) regime, with programmed pesticide use, and two lower input regimes with Supervised or Integrated pest and disease control systems. The present paper concerns the direct and indirect effects of these treatments on the interactions between polyphagous arthropod predators and cereal pests. Supervised pest and disease control has, on average, reduced pesticide use by 20-30%, and insecticide use by 80-90% relative to the Insurance treatment, whereas little difference has been achieved between Supervised and Integrated treatments. There have been both short term and longer term reductions in the populations of polyphagous predators in the Insurance area, depending upon the success of reinvasion and recruitment. Among the factors affecting recruitment is food supply, and there have been significant changes in the availability of alternative prey for polyphagous predators in the Insurance area. This paper will discuss the consequences of changes in alternative prey availability for prey selection by predators, and hence on the survival and recovery of predator populations under a high pesticide regime. The importance of such studies of the indirect effects of pesticides will be reviewed, and the problems that arise in the measurement and interpretation of such effects discussed.

ISOLATION AND SEQUENCE OF cDNA CLONES FOR CYTOCHROME P-450 FROM AN INSECTICIDE-RESISTANT STRAIN OF *MUSCA DOMESTICA*. R. Feyereisen, Departments of Entomology and Agricultural Chemistry, Oregon State University, Corvallis, OR 97331.

Insect cytochrome P-450 monooxygenases (mixed-function oxidases) are involved in essential endogenous reactions and in the metabolism of foreign chemicals. Although many cases of insecticide resistance result from increased detoxification by cytochrome P-450s, our understanding of the molecular genetics of resistance is sketchy.

A major form of cytochrome P-450 from phenobarbital-induced, insecticide-resistant houseflies was solubilized, purified and used as antigen to obtain P-450 antisera in rabbits. Two specific antisera were characterized by western immunoblotting and used to screen a housefly cDNA expression library constructed in the cloning vector lambda zap. Positive clones were purified, characterized and sequenced. The complete nucleotide sequence and deduced amino acid sequence of this housefly cytochrome P-450 is reported and compared to the sequence of cytochrome P-450s from other sources. Progress on the cloning and sequencing of a housefly NADPH-cytochrome P-450 reductase cDNA is also reported. These molecular probes for the insect cytochrome P-450 system will be used to study the molecular genetics of insecticide resistance. Supported by NIH grant GM39014.

MANAGEMENT OF PYRETHROID AND ENDOSULFAN RESISTANCE IN *HELIOTHIS ARMIGERA* (HUBNER) IN AUSTRALIA. N.W. Forrester*, M. Cahill and J.K. Layland, New South Wales Department of Agriculture Research Station, Narrabri, N.S.W., 2390, Australia.

Following field failures of pyrethroids against *Heliothis armigera* at Emerald in January 1983, a strategy was formulated to prevent further resistance to pyrethroids and resistance to insecticides of other chemical groups. This voluntary strategy, endorsed by all relevant sections of the agrochemical and crop growing industries, was implemented in September 1983, and has had since then, all but total compliance. It restricts pyrethroid use on all crops in most of eastern Australia to three applications over a 42 day period in the middle of the season. In addition, endosulfan is not recommended on cotton in the latter part of the season. The 42 day period corresponds to the minimum generation time of one of the 4 - 5 generations of *H. armigera* per year.

Monitoring results for the five seasons since the introduction of the strategy will be presented. The main factors affecting resistance frequency (insecticide selection pressure, immigration of susceptibles and cultivation of overwintering pupae) will be discussed. The biology of resistant and susceptible *H. armigera* will be compared and intra-specific competition studies (both laboratory and field) will be presented. The relative importance of the two major pyrethroid resistance genes (mixed function oxidases and nerve insensitivity) will be indicated by studies on field material throughout the season. The problems with using pheromone trapped male moths to monitor resistance will be highlighted.

SYNERGISM OF CARBARYL BY 4-CHLORO-1-NAPHTHYL-2 PROPYNYL ETHER IN *MUSCA DOMESTICA* (DIPTERA : MUSCIDAE). E.L. Hsu* and C.Y. Wei, Department of Plant Pathology and Entomology, National Taiwan University, Taipei, Taiwan, R.O.C.

To female housefly carbaryl alone was less toxic (LD 50: 128 ug/fly), but while it was combined with 4-chloro-1-naphthyl 2-propynyl ether (PE) or piperonyl butoxide (PB) at the ratio of 1:5, LD 50 of carbaryl for PE and PB treated group was 0.36 ug and 2.2 ug per fly respectively. Since PE also showed 50 times better than PB in terms of synergism at lower carbaryl/synergist ratio (1:2). PE was found to be able to improve the initial penetration rate of 14-C-carbaryl. The metabolism of 14-C-carbaryl alone or with PE in housefly also was traced. The data showed that the percentage of polar metabolites for 14-C-carbaryl alone treatment was higher than those of with PE synergist. Higher percentage of unchanged carbaryl in PE treated group was found at 2 hours after treatment. The major contents in n-hexane extractable portion were the unchanged carbaryl and a little hydroxycarbaryl. The contents in n-hexane unextractable portion were conjugates and 1-naphthol. The data showed the percentage of the contents in the n-hexane unextractable portion by 14-C-carbaryl alone treatment was higher than with PE synergist treatment. It is quite possible that PE synergist provides obstacle to MFO system in housefly.

MECHANISMS INVOLVED IN PERMETHRIN RESISTANCE OF THE COLORADO POTATO BEETLE *LEPTINOTARSA DECEMLINEATA* SAY (CHRYSMELIDAE) WITH PARTICULAR REFERENCE TO KNOCKDOWN RESISTANCE (KDR). P.M. Ioannidis*, E.J. Grafius, Department of Entomology, Michigan State University, East Lansing, Michigan 48824 U.S.A.

Resistance of Colorado Potato Beetle (CPB) to permethrin was detected, in several field collected strains in Michigan. Maximum observed field resistance was 43-fold with LD₅₀ = 16.8 µg./beetle. Dosage-mortality studies with adults were conducted using the standard topical application method (FAO No. 12). Synergistic experiments were also carried out. Synergist ratios used were 1/5 insecticide/synergist. Piperonyl butoxide (PBO), an inhibitor of multifunction oxidase enzymes, suggest that permethrin is susceptible to oxidative detoxication, synergist ratio (SR) = 6.9. Tests with DEF, an inhibitor of esterases, also showed some synergism (SR = 2.7). However resistance of CPB to permethrin can not be explained sufficiently by these detoxication mechanisms because PBO and DEF were unable to entirely overcome the detected resistance. Some of the tested field resistant strains to permethrin were also resistant to DDT (83-fold, LD₅₀ > 1000 µg/beetle) bioassays with DDT & PBO (SR = 3.9) and DDT + chlorfenvethol (SR = 1.2), an inhibitor of dehydrochlorinase gave low synergism. The permethrin-DDT cross resistance and the low synergism with DDT lead us to the conclusion that another possible mechanism for permethrin resistance is probably the KDR factor (site insensitivity).

BIOCHEMICAL AND TOXICOLOGICAL PROPERTIES OF A MALATHION-RESISTANT AND -SUSCEPTIBLE STRAIN OF DIAMONDBACK MOTH, *PLUTELLA XYLOSTELLA* L. (LEPIDOPTERA: PLUTELLIDAE). C.J.W. Maa* and S.H. Guh, Institute of Zoology, Academia Sinica, Taipei, Taiwan 11529, Republic of China.

The diamondback moth, *P. xylostella* L., collected from a vegetable field was used for the toxicological study on malathion resistance. Various pesticides have been used in the field for pest control since the last decade. Two strains (ST-26 and ST-12) of the diamondback moth, selected by means of the isofemale pairing method, showed different susceptibility to malathion treatment. The LD₅₀ (24hr) to malathion for the strain ST-26 and ST-12 was 88 ug/larva and 6 ug/larva respectively. A study of malathion metabolism in these larvae revealed that the content of malaoxon alpha monoacid was 135 pmole/larva in the strain ST-26 and 76 pmole/larva in the strain ST-12 six hours after treatment. The zymogram of isozymes obtained by PAGE showed that a band designated as E₈ from the strain ST-26 was more resistant to malaoxon and mevinphos than that of the strain ST-12, and this band was less susceptible to paraoxon. It is postulated that the E₈ isozyme was at least, partially associated with malathion resistance of the strain ST-26.

MOLECULAR MECHANISMS OF ALDRIN RESISTANCE IN WESTERN AND NORTHERN CORN ROOTWORMS. C.A. Mullin* and B.D. Siegfried, Pesticide Research Laboratory, Department of Entomology, Pennsylvania State University, University Park, PA 16802, USA.

Pioneer populations of western corn rootworm (*Diabrotica virgifera virgifera* LeConte, WCR) in central Pennsylvania are about 500 times more resistant to aldrin than sympatric populations of the northern corn rootworm (*D. barberi* Smith & Lawrence, NCR). Similar levels of cyclodiene resistance were found by topical and ingested routes of exposure. Maintenance of this differential resistance is remarkable since both species have similar biologies and resistance capabilities, and have not received field applications of cyclodiene insecticides for over a decade. The roles of penetration, metabolism, alternative host plant feeding, and action at the γ-aminobutyric acid (GABA)-regulated chloride ionophore in *Diabrotica* resistances to cyclodienes were investigated. Penetration of ¹⁴C-aldrin into both resistant WCR and susceptible NCR is very rapid. Rates of metabolism of aldrin to its epoxide dieldrin, and of dieldrin to its trans-diol are similar between the two species both *in vivo* and *in vitro*. Metabolism in the nerve cord is also similar. However, midgut cytochrome P-450 epoxidase in NCR is more inducible by diet shifts from corn to squash or sunflower than that of WCR, and may explain the wider host range of NCR. Increased epoxidation of aldrin to dieldrin without subsequent detoxification may explain up to 10-fold, diet-dependent increases in aldrin susceptibility. Nevertheless, evidence to date supports a modification in the GABA-chloride ionophore, and not a penetration barrier or increased metabolism, for long-term development of aldrin resistance in WCR.

MONITORING, SELECTION AND GENETIC ANALYSIS OF RESISTANCE TO PYRETHROIDS IN THE AUSTRALIAN SHEEP BLOWFLY, *LUCILIA CUPRINA* (WIEDEMANN) (DIPTERA: CALLIPHORIDAE). N. Sales*, G.W. Levot and P.B. Hughes, Department of Agriculture, New South Wales, P.M.B. 10, Rydalmere, N.S.W. 2116, Australia.

The response of field populations to the pyrethroid deltamethrin was determined by bioassay. A normal distribution of LC₅₀ values was found, with no indication of resistance despite the widespread use of deltamethrin on sheep to control lice. There was no cross-resistance to deltamethrin from existing organophosphate (OP) resistance nor from previous use of DDT. Selection with deltamethrin on a combined field strain CFS increased the LC₅₀ gradually over the first 20 generations until it stabilised at approximately 25x that of the unselected CFS. This laboratory-induced resistance extended to other pyrethroids, cypermethrin (16x), cyhalothrin (25x) and cycloprothrin (10x), and increased the existing resistance of CFS to the OP diazinon (11x) and the carbamate, butacarb (83x). Genetic analysis of CFS revealed that the selection response was polygenic with major contributions from chromosomes 4 and 6. Genes on both these chromosomes also cause OP and carbamate resistance in *L. cuprina*. Possible gene interaction has occurred between existing resistance genes and others accumulated during selection.

INSECTICIDE INDUCTION OF ENZYME MODIFICATION IN FOURTH INSTAR *Aedes Aegypti* LARVAE. P.E. Yeager*, and R.A. Nunanaker, Department of Plant, Soil and Insect Sciences, University of Wyoming, P.O. Box 3354, Laramie, Wyoming, USA 82071, and USDA, Agricultural Research Service, Arthropod-borne Animal Diseases Research Laboratory, P.O. Box 3965, Laramie, Wyoming, USA 82071.

Enzyme modifications resulting from exposure to insecticides were studied in fourth instar larvae of *Aedes aegypti*. Larvae were exposed to malathion, cispermethrin, or carbaryl at three sublethal or one lethal concentration. Five time intervals (2, 4, 8, 16 and 32 hours) were observed for each of the sublethal concentrations. Enzymes and non-enzymatic proteins were separated using isoelectric focusing on polyacrylamide gels. Enzyme modifications were quantified using a scanning laser densitometer.

Enzyme loci that were studied include: nonspecific esterases (EST) and leucine aminopeptidase (LAP). Modifications in the general protein (Gp) electrophoretic pattern were also studied. Several individual bands and/or band groups were observed using specific histochemical stains. Malathion and carbaryl reduced LAP activity markedly, whereas all three insecticides affected the activity of EST and Gp. Carbaryl induced additional protein bands and an overall shift towards the anode (pH 3) that correlated with the concentration of the insecticide.

DIFFERENTIAL TOXICITY OF AVERMECTIN B₁ TO LARVAE OF *SPODOPTERA LITTORALIS* BOISD. (LEPIDOPTERA: NOCTUIDAE). P.T. Christie*, T.S. Corbitt and D.J. Wright, Imperial College Silwood Park, Ascot, Berkshire, U.K. SL5 7PY.

The toxicity of avermectin B₁ (AVM) has been reported to vary markedly within the lepidoptera. We have shown that the relative toxicity (LD₅₀, ng/mg) of topically-applied AVM decreased 8-fold from the second to fourth larval instar of *S. littoralis* but increased by 3 and 1000-fold from the fourth to the fifth and sixth instars, respectively. The activity of AVM against fourth and fifth instars was increased 5-fold by the microsomal oxidase inhibitor piperonyl butoxide (PB). Such marked differences between instars were not found with malathion or the pyrethroid cyhalothrin, nor was their activity appreciably enhanced by PB. Injection of AVM increased its toxicity 8-fold against the fifth instar but decreased its toxicity 2-fold against the sixth instar when compared with topical application.

The results suggest that the relative insensitivity of some larval stages of *S. littoralis* to AVM can be accounted for at least in part in terms of enhanced metabolism and reduced penetration.

FUNGI AS SOURCES OF INSECTICIDAL COMPOUNDS. P.F. Dowd, USDA/ARS, Northern Regional Research Center, 1815 North University Street, Peoria, IL 61604.

In connection with ecological studies on the interactions between insects and mycotoxin-producing fungi, several fungus-derived compounds were discovered to have insecticidal/insectistatic properties. For example, mycotoxins and associated compounds that could be naturally encountered by the fall armyworm [*Spodoptera frugiperda* (J. E. Smith)] and the corn earworm [*Heliothis zea* (Boddie)] were examined for toxicity to these insects. Several trichothecenes, including those with relatively low vertebrate toxicity, were insecticidal and insectistatic at 250 and 25 ppm, respectively, in the diet of the insects. Several indole alkaloids have also been found to be insecticidal/insectistatic. These include compounds of low vertebrate toxicity as well as compounds that have greater relative toxicity to insects vs. vertebrates (>50% insect growth reduction at 25 ppb). Other fungal metabolites are active as well.

Fungal metabolites may act synergistically with mycotoxins, phytotoxins, or commercial insecticides. Kojic acid synergized the toxicity of aflatoxin B₁ and some pyrethroids. Other fungal metabolites can act synergistically, depending on the toxin with which they are combined.

TOXICOKINETICS AND METABOLISM OF THE PHOTOTOXIC ALLELOCHEMICAL α -TERTHIENYL IN THREE HERBIVOROUS LEPIDOPTERA. S. Iyengar*, J.T. Arnason and B.J.R. Philogène, Department of Biology, University of Ottawa, Ottawa, Ontario, Canada K1N 6N5.

Alpha-T, a phototoxic secondary metabolite of various Asteraceae shows considerable variation in its insecticidal activity to *Manduca sexta*, *Ostrinia nubilalis* and *Heliothis virescens*. To investigate this differential response, the toxicokinetics and metabolism of ³H-alpha-T was studied in the three species. Elimination of ³H-alpha-T is much more rapid in *O. nubilalis* (t_{1/2}=8.5h) as compared to *H. virescens* (t_{1/2}=22h) or *M. sexta* (t_{1/2}=48h). Furthermore alpha-T was metabolised 16 and 30 times faster by *H. virescens* and *O. nubilalis* microsomal fractions respectively as compared to *M. sexta*. Examination of the cytochrome P-450 levels indicated *O. nubilalis* and *H. virescens* having 3 and 4 times more cytochrome P-450 than *M. sexta*. The results suggest that increased metabolism mediated by mixed function oxidases leading to rapid clearance is one method by which resistant insect herbivores deal with this type of allelochemical in host plants.

TOXICITY OF THE VOLATILE OIL OF *HEMIZYGIA WELWITSCHII* TO ADULT FEMALE MOSQUITO *CULEX ALBIVENTRIS*. J.I. Olafifa* and A.A. Jibodu, Department of Plant Science, Obafemi Awolowo University, Ile-Ife, Nigeria.

Volatile oil of *Hemizygia welwitschii* (Rolf), was applied onto filter paper discs inside 200 and 2500 ml glass beakers covered with cheese cloth holding female *Culex albiventris*. The volatile oil exhibited fumigant action, as the mosquitoes experienced knockdown and mortality within a few minutes of introducing the paper disc. In a 200 ml glass, 10 µl of oil on the paper disc gave 50% mortality after 9 minutes of exposure while 3 µl gave the same result after 23 minutes. In the 2500 ml glass, an oil concentration of 15 µl gave 50% mortality after 40 minutes of exposure while 40 µl gave 50% mortality after 17.5 minutes. The higher the concentration the shorter the lethal time. The implications of the present results in mosquito control in Nigerian homes using indigenous botanical resources is discussed.

EFFECT OF CYROMAZINE ON LARVAL GROWTH AND DEVELOPMENT OF THE TOBACCO HORNWORM, *MANDUCA SEXTA* (L.) (LEPIDOPTERA: SPHINGIDAE). P.B. Hughes*, W.C. Dauterman and N. Motoyama, Toxicology Program, North Carolina State University, Raleigh, NC 27695, U.S.A.

Cyromazine (2-cyclopropylamino-4,6-diamino-s-triazine) induced symptoms ranging from cuticular melanization to rupture of body walls when fed to 5th instar larvae of *M. sexta* in artificial diet. At >20 ppm cyromazine, larvae became thin, elongated and swollen in the intersegmental regions and ruptured easily when handled. These symptoms became evident within a few hours of feeding on treated diet and larvae did not develop to the pupal stage. At lower doses, development proceeded to the pupal stage but with symptoms varying from small size to abnormal pupal cuticles and consequent failure to eclose. No difference was found in the ratio of chitin to body weight between cyromazine-treated and control 5th instar larvae, suggesting that cyromazine does not directly affect chitin production. Larvae excreted cyromazine rapidly, while the level in the haemolymph remained relatively constant during feeding. However, cyromazine accumulated in the body wall increasingly with time. The observations suggest that cyromazine inhibits growth and/or expansion of the body wall.

β -GLUCOSIDASE IN FOUR PHYTOPHAGOUS LEPIDOPTERA. S. J. Yu, Department of Entomology & Nematology, University of Florida, Gainesville, Florida 32611, U.S.A.

β -Glucosidase in fall armyworm (*Spodoptera frugiperda*) larvae was studied using helicin as substrate. Enzyme activity was found in various tissues, with the midgut soluble fraction being the most active. The apparent Km and Vmax values for the enzyme were 0.63 mM and 17.39 nmol/min/mg protein, respectively. The enzyme was fairly stable for 8 weeks when stored at 0°C. Activity was mainly located in the 60% fraction when the soluble fraction was fractionated with ammonium sulfate. The system also hydrolyzed a variety of glucosides including toxic plant allelochemicals such as solanine, amygdalin, prunasin, tomatine, limanarin and sinigrin. Substrate specificity of β -glucosidase was different in fall armyworms, velvetbean caterpillars, cabbage loopers, and corn earworms, suggesting a qualitative difference in the enzyme among these species. Activity toward cyanogenic glucosides appeared to be high in the velvetbean caterpillar probably due to higher levels of cyanogenic glycosides in its legume hosts.

A COMPARATIVE INVESTIGATION OF THE TEMPERATURE DEPENDENCE OF THE TOXICITY OF LIPID AMIDES AND PYRETHROIDS. M.D.V. Moss* and B. Dealey, Wellcome Research Laboratories, Ravens Lane, Berkhamsted, Herts, England HP4 2DY.

The toxicity to *Musca domestica* of three lipid amides pellitorine, [(2E,4E)-N-Isobutyl-2,4-decadienamide], B81H [(2E,4E)-N-Isobutyl-9-(3 trifluoromethyl benzyloxy)-2,4-nonadienamide] and A518H [(2E,4E)-N-Isobutyl-11-(3,5-dichlorophenoxy)-2,4-dodecadienamide] was compared with that of two pyrethroids, S-bioallethrin and deltamethrin at 15, 23 and 35°C. Toxicity assessments were carried out from 10 minutes to 4 days so that any changes in temperature dependence with time could be detected. In the early stages of the experiment pellitorine and S-bioallethrin showed strong negative temperature dependence while B81H and deltamethrin showed a positive dependence. A518H showed no activity at the doses used. By the time the end point was reached after 4 days all 5 compounds showed a negative temperature dependence when comparing 15 and 23°C. Only deltamethrin continued to show such a temperature dependence when the temperature was raised to 35°C. Discussion of these results will include reference to the relative knockdown/kill effects of these compounds and the effect of temperature on the magnitude of, and time to attain, maximal effect.

HETEROPTERA, A VERY PESTICIDE SENSITIVE NON-TARGET INSECT GROUP IN CEREAL FIELDS. Niels Elmegaard, Centre for Terrestrial Ecology, Thoravej 8, DK - 2400 Copenhagen NV, Denmark.

In a spring barley field the Heteroptera fauna in pesticide treated plots were analysed and compared to untreated plots. In treated plots herbicide (MCPA + 2,4-D + dichlorprop), growth regulator (ethephon), fungicide (propiconazole), and insecticide (cypermethrin, pirimicarb) were applied. On June 27 and July 18 D-vac sampling was carried out at four different distances from the field border, i.e. 3, 48, 84, and 120 metres.

In pesticide treated plots the number of Heteroptera was reduced by 90% in mid-field compared to untreated plots. In border areas (3 m) the reduction was less due to immigration. The effect of pesticides on Heteroptera species are discussed according to their phenology and distribution in fields. Also aspects of the ecological significance of Heteroptera in cereal fields are discussed.

LE CALIBRAGE DE L'INSTRUMENT ABEILLE PAR RAPPORT AU PLOMB. G.Celli*, C.Porini, G.Siligardi*, P.Mazzali*. Istituto di Entomologia "G. Grandi" Università Via F. re 6, 40126 Bologna, P.M.P. USL 9 Reggio Emilia, P.M.P. USL 16 Modena (Italy).

Depuis quelques années nous utilisons l'abeille comme insecte-test pour examiner la pollution provoquée par les métaux lourds dans la ville. Plusieurs interventions ont déjà été effectuées à Rome, Florence, Pise et Arezzo. En 1987, nous avons placé dans la ville de Modène (Emilie-Romagne Italie), dans des positions stratégiques, cinq ruches-station pour déterminer la pollution par certains métaux lourds, le plomb en particulier, à travers les analyses chimiques du miel, des larves et du pollen. En utilisant à chaque ruche un mesureur automatique de la pollution on a voulu obtenir le "calibrage" de cet instrument biologique. Les résultats obtenus indiquent que le développement de la pollution du miel ($\bar{x}$ (ppm) juin: 0.66, juillet: 0.50, août: 0.308, septembre: 0.55) par le plomb est semblable à celui qui a été relevé par les stations automatiques ($\bar{x}$ ($\mu\text{g}/\text{m}^3$) juin: 0.447, juillet: 0.40, août: 0.362, septembre: 0.464). Par contre, le développement de la pollution du pollen ($\bar{x}$ (ppm) juin: 74.7, juillet: 3.77, août: 5.10, septembre: 11.4) et des larves ($\bar{x}$ (ppm) juin: 1.90, juillet: 0.90, août: 1.22, septembre: 1.39) apparaît plus différé.

DEGRADATION OF MANCOZEB DURING STORAGE AND COOKING AND ITS PERSISTENCE ON BRINJAL PLANTS. H.C. Agarwal* and Uday Kumar, Department of Zoology, University of Delhi, Delhi-110007, India.

Mancozeb is the most used ethylenebisdithiocarbamate fungicide in India. Its use was favoured by its low mammalian toxicity and persistence. However, formation of Ethylenethiourea (ETU), a teratogen and suspected carcinogen, during manufacture, storage and metabolism in plants is of grave concern.

Studies on degradation during storage upto 20 months revealed 107 to 245 ppm ETU in the commercial formulations. Significant decrease in the amount of parent compound was also observed during storage. When ^{14}C -mancozeb was sprayed on the potted brinjal plants about 24% of it was present as ETU after 21 days in the fruits. However, the level of mancozeb decreased significantly and showed a rapid dissipation with a half life of 15.1 days. Cooking of brinjals fortified with ^{14}C -mancozeb also resulted in 17 to 43% ETU.

LONGEVITY OF ZECTRAN® RESIDUES COMPARED TO RESIDUAL TOXICITY TO SPRUCE BUDWORM LARVAE. B.V. Helson* and K.M.S. Sundaram, Forest Pest Management Institute, P.O. Box 490, Sault Ste. Marie, Ontario, Canada P6A 5M7.

Potted white spruce trees were treated with Zectran (mexacarbate) at 100 g AI/ha. Mexacarbate residues in needles declined 99% within 3 days and reached non-detectable levels (<0.01 ppm) by 10 days after treatment. Mortality of spruce budworm larvae on foliage from these trees declined more gradually from 100% initially to 22% when exposed 10 days after treatment. Gas chromatographic analysis of metabolites in needles revealed that by 3 days, 4-methylformamido-3,5 xylyl N-methyl carbamate was present at levels 19-32x higher than mexacarbate. This metabolite was found to be about 7x less toxic to spruce budworm larvae than mexacarbate on treated needles. Another metabolite, 4-methylamino-3, 5 xylyl N-methylcarbamate was detectable for one day following treatment. The toxicity of this metabolite (LD50 = 0.016 µg/needle/larva) was similar to mexacarbate (LD50 = 0.018 µg/needle/larvae). The possible role of these metabolites in the observed residual toxicity of the Zectran treatment will be discussed.

LABORATORY SIMULATION OF ENHANCED IN SITU DEGRADATION OF FIVE PESTICIDES COMBINED IN SOIL AMENDED WITH VARIOUS ADDITIVES. R. E. Johnsen, Department of Entomology, Colorado State University, Fort Collins, Colorado, USA 80523

Soil treated with the herbicides atrazine, trifluralin, 2,4-D(iso-octyl ester) and the insecticides parathion and heptachlor together were studied to determine their combined degradation in a time-course study. Treated soils were incubated with or without cattle manure (10%w/w) or a dry commercial microbial culture (Superbugs) (10%w/w), formulated for degradation of wastes. Untreated soils and treated soils containing HgCl₂ as a microbial inhibitor, served as controls. Soils were analyzed for residues at 0, 7, and 14 days and 1 and 2 months following treatment. All five pesticides were degraded over time with the most rapid degradation found for parathion and 2,4-D. Details of the degradation and the analytical scheme, employing GLC-EC, will be discussed.

PERSISTENCE, BINDING AND DEGRADATION OF DDT AND HCH IN A SANDY LOAM SOIL UNDER FIELD AND LABORATORY CONDITIONS IN DELHI, INDIA. M.K.K. Pillai, Department of Zoology, University of Delhi, Delhi-110 007, India.

Persistence and binding capacity of ¹⁴C-DDT and ¹⁴C-HCH were studied for one year in a sandy loam soil of Delhi, India after surface treatment during monsoon, winter and summer seasons under field conditions. Both DDT and HCH dissipated more rapidly under the Indian subtropical climate than reported for temperate regions. After one year the final soil burden of DDT varied from 33 to 36% and of HCH from 14 to 15% of the initial concentrations in the different experiments. HCH bound more with soil than DDT. The observed time for 50% dissipation of DDT varied from 60 to 120 days while in the case of HCH it varied from 30 to 45 days. Laboratory studies revealed that high soil temperature and solar irradiation increased the rate of volatilization of both DDT and HCH though mineralization and biodegradation of these insecticides were minimal. The present data indicate that dissipation of DDT and HCH was largely due to volatilization.

EFFECT OF MILK AND MEAT PROCESSING ON PESTICIDE RESIDUE ELIMINATION. G.D. Jadhav, Marathwada Agricultural University, Parbhani 431 402, India.

Cow and buffalo milk samples having DDT and HCH residues of 1.015 & 0.220 and 1.235 & 0.402 ppm, respectively, were subjected to various processing methods, such as heating/boiling, curd making, butter preparation and ghee making. The effects of these processing methods were assessed by gas chromatography. Heating/boiling of milk did not result in much DDT elimination. However, HCH was eliminated to the extent of 67.2%. Curd prepared from such cow and buffalo milk indicated increase in DDT and HCH concentration by 33.9 & 0.6% and 18.1 & 27.6%, respectively. Butter prepared from the cow and buffalo milk also indicated an increase in the concentration of DDT and HCH by 109.2 & 76.8% and 182.7 & 96.3%, respectively. Similarly, ghee prepared from the cow and buffalo milk had an increased concentration of DDT and HCH of 174.8 & 125.0% and 190.8 & 131.8%, respectively. Meat samples had a maximum of 3.925 ppm DDT and 2.895 ppm HCH residues when subjected to washing by water; HCH elimination was a little more ranging from 75 to 79.9%, and DDT elimination was comparatively less, ranging from 33.7 to 62.8%. Similarly, boiling/cooking helped more in elimination of HCH residues (96.6 to 98.2%) than DDT (66.4 to 74.8%).

VERTICAL MOBILITY AND ACCELERATED DEGRADATION OF INSECTICIDES APPLIED TO TURFGRASS. H. D. Niemczyk*, J. Majchrzak, Z. Filary and H. R. Krueger, Department of Entomology, OARDC/The Ohio State University, Wooster, Ohio, U.S.A. 44691.

Analysis of thatch (accumulated dead organic matter at the soil surface) and underlying soil for residues 1 and 2 weeks after application of isofenphos, diazinon, trichlorfon, ethoprop, chlorpyrifos, isazofos, fonofos, carbaryl and bendiocarb, showed 98 to 99% from all but trichlorfon were in the thatch. Residues of the remaining materials in the first 2.5 cm of soil did not exceed 0.8 ppm over 34 weeks of sampling.

Isofenphos, initially effective against scarabaeid larvae in turfgrass when first used in 1981, became less effective after two or more years of use. Thatch from a golf course where isofenphos failed was tested *in vitro* to ascertain whether a capacity to rapidly degrade this insecticide and three others had developed. Supernatant from aqueous suspensions of thatch were injected into buffered nutrient solutions containing ca 10 ppm isofenphos, diazinon, isazofos or carbaryl. After incubation in darkness at 20°C, analysis by HPLC showed isofenphos and carbaryl degraded to <1 ppm in 24 h and diazinon in 13 days. Isazofos and test standards showed no degradation. Field application of these insecticides to the site and retesting of the thatch 6 weeks after application, showed degradation of isazofos and the other insecticides. Field samples of thatch showed residues of isofenphos and carbaryl decreased from 8.3 and 46.7 ppm at zero days to <1 ppm in 7 and 14 days, respectively; diazinon from 21.4 to 6.3 ppm and isazofos from 15.2 to 6.2 ppm in 14 and 21 days, respectively.

#18

INSECTICIDE RESISTANCE BIOASSAYS FOR *HELIOTHIS VIRESCENS*, FABRICIUS (LEPIDOPTERA, NOCTUIDAE); COMPARISON AND ASSESSMENT. D. Badulescu, Reading University, Department of Zoology, Reading, Berks., England; currently at, ICI Mexico, San Lorenzo 1009, Mexico City 03100, DF, Mexico.

Topical application, cotton foliage residue test, larval-dip test and adult-vial test are common testing procedures in resistance monitoring programs in cotton growing areas. These four different bioassays were compared in order to assess the diagnostic performance, their practicality at user's level and the correlation of the rendered data. Two strains were used; the resistant strain called PEG, collected in the USA cotton areas and a reference susceptible strain called BRC. Significant (statistical) differences in the dose-mortality responses and resistance ratios of each of the bioassays seemed to indicate that the detected level of resistance was a function of the type of bioassay employed.

#19

EFFECT OF SEVERAL SYNERGISTS ON THE TOXICITY OF RESMETHRIN TO CIGARETTE BEETLES. H.J. Benezet*, C.W. Helms, R. Baucom and M.R. Rodgers, R. J. Reynolds Tobacco Co., Winston-Salem, North Carolina.

Resistant insects can enzymatically detoxify pyrethroid insecticides. The cigarette beetle is highly resistant to type I pyrethroids, e.g. resmethrin, but susceptible to type II pyrethroids, e.g. cypermethrin. Resistance to pyrethroids can be enzymatic. The use of synergists which inhibit Mixed Function Oxidase (MFO) or esterase enzymes can measure the significance these systems play in determining resistance. Competitive inhibitors (piperonyl butoxide and MGK 264) of the MFO system did not significantly increase the toxicity of resmethrin. Inhibitors of esterases (EPN and malathion) had no effect on toxicity to the cigarette beetle. Cigarette beetle resistance to the toxicity of type I pyrethroids may not be directly related to metabolism of the pyrethroid by MFO or esterase enzymes.

#20

MONITORING INSENSITIVE ACETYLCHOLINESTERASE IN INSECTICIDE RESISTANT MOSQUITO POPULATIONS. B.C. Bonning* and R.H. French-Constant, London School of Hygiene and Tropical Medicine, Keppel Street, London, WC1E 7HT.

Insensitive acetylcholinesterase is known to confer resistance to organophosphorus and carbamate insecticides in *Culex pipiens pipiens* Say, *Anopheles albimanus* Wiedemann and *A. nigerrimus* Giles. Microtitre assays in the presence of inhibitors were assessed by absorbance at fixed end-points and by measuring rates of reaction. Data are compared for different species and rapid methods for defining genotypes using a kinetic plate reader are described. Correct identification of genotypes was confirmed by crossing resistant and susceptible strains. These techniques were used to examine genotype frequencies both in laboratory colonies kept under different selection regimes and in field populations.

#21

GEOGRAPHIC VARIABILITY OF INSECTICIDE SUSCEPTIBILITY OF *SPODOPTERA EXIGUA* (HUBNER) (LEPIDOPTERA: NOCTUIDAE) TO TWO PYRETHROIDS AND A CARBAMATE IN SOUTHERN AND BAJA CALIFORNIA, U.S.A. AND MEXICO. M.J. Brewer* and J.T. Trumble, Department of Entomology, University of California, Riverside, CA, U.S.A. 92521.

Monitoring for insecticide resistance to fenvalerate, permethrin, and methomyl in *S. exigua* was carried out in geographically separated locations, 1986-1987. Susceptibilities to the toxins were documented using an attractant trap bioassay technique (ATT) in the field (toxins incorporated into adhesive of pheromone sticky traps) and less frequent laboratory topical bioassay of larvae.

Using a susceptible laboratory strain for comparison, methomyl susceptibility was geographically and temporally more variable than either pyrethroid. Resistance ratios (RR) for adults using ATT ranged from 4 to 30 at LD50. Fenvalerate susceptibility was variable (3 to 12 RR) compared to permethrin (2 to 5 RR).

Relationship of these results to larval toxicity and field use of insecticides will also be presented.

#22

PERMETHRIN AND METHYL PARATHION RESISTANCE MECHANISMS IN *HELIOTHIS VIRESCENS* (F.) (LEPIDOPTERA: NOCTUIDAE). T.M. Brown* and P.K. Bryson, Department of Entomology, Clemson University, Clemson, South Carolina, USA 29634-0365.

Mechanisms involved in resistance appear to include target site insensitivity, increased detoxication (as indicated by synergist activity), and reduced cuticular penetration. Methyl parathion resistance involves reduced sensitivity to inhibition in the target acetylcholinesterase. Our preliminary results indicate that this mechanism is inherited as a dominant trait. We will present results of additional studies of this inheritance. Synergist activities with permethrin, methyl parathion and DDT in several strains suggest that there are at least two detoxicative mechanisms involved. Inheritance of permethrin resistance involves one major factor and at least one less potent mechanism. Preliminary results of linkage tests will be presented.

#23

TOXICOKINETICS AND METABOLISM OF DIMBOA (2,4-dihydroxy-7-methoxybenzoxazin-3-one) AND MBOA (6-methoxybenzoxazolinone) IN THE EUROPEAN CORN BORER, *OSTRINIA NUBILALIS*. F. Campos*, J.T. Arnason, B.J.R. Philogène, J. Atkinson, P. Morand, N.H. Werstiuk. Faculty of Science, University of Ottawa, Ottawa, Ont. K1N 6N5.

DIMBOA and its degradation product MBOA are naturally occurring compounds in the corn that reduce growth and development of the larvae of the European corn borer, *Ostrinia nubilalis*. In feeding trials with MBOA and DIMBOA, accumulation in the insect increased from 4th to 5th instar, but declined to less than half as the insect entered into pupae and adult stages. In tracer studies with MBOA and DIMBOA, both uptake and excretion of MBOA increased linearly with concentration, while with DIMBOA there was a decrease in the uptake and excretion at the intermediate dose. Metabolism studies indicate that DIMBOA is converted to MBOA and other metabolites both in the insect and frass. MBOA fed insects also show metabolism of the compound both in the insect and frass.

#24

BIOLOGICAL AND CYTOLOGICAL ANALYSIS OF THE EFFECTS OF DIETARY PHOSPHORUS RADIOISOTOPES ON INSECT FERTILITY. Judy Ju-Hu Chiang, Department of Entomology, and Robert Kuo-Cheng Chen, Department of Environmental Engineering, National Chung Hsing University, Taichung, Taiwan, Republic of China.

Green rice leaf-hoppers (*Nephotettix bipunctatus apicalis* Motschulsky) were fed on radioactive diets containing, ^{32}P as phosphate with specific activity of 0.1 and 0.5 microcurie/ml. Germ cells were examined by the light microscope, scanning electron microscope and transmission electron microscope. Changes in germ cell structure and adverse effects of fertility were observed. Damage to lysosomes was believed to be responsible for destruction of protein. Damage to mitochondria was associated with abnormal insect development. The damage to centrioles was associated with loss of sperm activity.

#25

TOXICOLOGICAL AND BIOLOGICAL PARAMETERS ASSOCIATED WITH THE DEVELOPMENT OF MALATHION RESISTANCE IN *CADRA CAUTELLA* AND *PLODIA INTERPUNCTELLA*. W. R. Halliday, Stored-Product Insects Research and Development Laboratory, USDA-ARS, P.O. Box 22909, Savannah, GA 31403 USA.

Cadra cautella and *Plodia interpunctella* are closely related Pyralid moth species in which resistance to malathion is widespread and severe. *Cadra* is about 7.5 X less sensitive to malathion than *Plodia*. The reasons for this specificity to malathion were investigated. Pharmacokinetic and metabolism studies using susceptible larvae were conducted to explain this difference. High malathion resistance in *Plodia* is due to malathion carboxylesterase activity. The genetic basis was investigated using enzyme from individual midgut homogenates incubated with radiolabeled malathion. Results suggest that multiple alleles exist for malathion resistance in *Plodia*. Fitness of resistant and susceptible *Plodia* was investigated by measuring the % egg hatch, time to adult emergence, % adult emergence, and average number of progeny per female. Resistant strains were found to have greater variability in % egg hatch and average number of progeny. These results are discussed in terms of how malathion resistance develops in field situations.

#26

SUBSTITUTED PYRIMIDINE-2-THIOLS: ANTIFERTILITY AGENTS AGAINST THE RED COTTON BUG. H. Kaur¹, S.S. Dhillon and R. Sandhu, Department of Zoology, Punjabi University, Patiala-147002, India.

Six newly synthesized substituted Pyrimidine-2-Thiols have been tested for their antifertility effects on *Dysdercus koenigii*. Assessment of the decline in fecundity and fertility of the bug is a pointer that these compounds bring down the multiplication rate of the pest. But their capacities to do so are differential. Maximum reproduction control (100%) has been obtained by the use of 1-(3-Nitrophenyl)-4,4,6-Trimethyl-1H,4H-Pyrimidine-2-Thiol (3 NTPT) at a dose of 15mg/5ml acetone, 1-Allyl-4,4,6-Trimethyl-1H,4H-Pyrimidine-2-Thiol (ATPT) at a dose of 25mg/5ml acetone, and 4,4,6-Trimethyl-1H,4H-Pyrimidine-2-Thiol (TPT) and 1-Phenyl-4,4,6-Trimethyl-1H,4H-Pyrimidine-2-Thiol (PTPT) each at dose of 50mg/5ml acetone. However, treatment with 1-(2-Methoxyphenyl)-4,4,6-Trimethyl-1H,4H-Pyrimidine-2-Thiol (MTPT) and 1-(2-Nitrophenyl)-4,4,6-Trimethyl-1H,4H-Pyrimidine-2-Thiol (2 NTPT), each at 50mg/5ml acetone result only in 99.62% and 86.45% of reproduction control respectively.

#27

IMPACT OF CERTAIN INSECTICIDE RESIDUES ON SOIL MICROFAUNA IN SUBTROPICAL CONDITIONS. C.P. Kaushik, Department of BioSciences, M.D. University, Rohtak-124001, Haryana, India.

The persistence of DDT and HCH in a sandy loam soil and impact of the insecticide residues on soil nematodes, mites, collembolans, insects and their larvae was investigated for a period of 5 months. The nematodes outnumbered the arthropods in the soil. Among the soil arthropods Collembola was the predominant group. In the soil treated with HCH the nematode population showed a steady increase with time as compared to controls. However, DDT treatment resulted in an increase in the population of plant parasitic nematodes and an initial decrease in case of saprobionts. The DDT and HCH treatments did not show any significant change in the arthropod population in the soil when compared with the controls. It appears that HCH and DDT treatments used at the rates normally recommended in Indian agricultural practice had no or little effect on the soil microfauna probably due to their rapid dissipation.

#28

ROLE OF MONOOXYGENASES IN RESISTANCE MECHANISMS OF *HELIOTHIS VIRESCENS* FABRICIUS (LEPIDOPTERA: NOCTUIDAE) TO METHYLPARATHION. T. Konno^{*}, W. C. Dauterman and E. Hodgson, Toxicology Program, Box 7633, North Carolina State University, Raleigh, NC 27695, U.S.A.

Studies were conducted on the resistance mechanisms in a field strain (R) of *H. virescens* larvae to methyl parathion, when compared with a susceptible laboratory strain (S). In vitro, monooxygenase activity responsible for desulfurating methyl parathion (MP) to methyl paraoxon (MPO) was 2.5 times lower and phosphotriester hydrolase activity, hydrolyzing MPO, was 5 times higher in R than in S. No differences were observed in glutathione S-transferase activity and acetylcholinesterase inhibition. In vivo, the amount of MP decreased 10% more in S than in R following the first 1 hr after injection. The amount of formed MPO increased in S from 8% in 20 min to 18% in 6 hr, while it stayed at a much lower level in R, being 5% in 20 min and 2% in 6 hr. The amount of injected MPO decreased 20% more in R than in S in 1 hr. The amount of penetrated MP was 2 times less in R than in S following the first 12 hr after topical application, but was equal 24 hr later.

These results indicate that lower monooxygenase activity as well as higher phosphotriester hydrolase activity are mainly responsible for resistance to MP in *H. virescens*.

#29

RESISTANCE MECHANISM OF THE RICE STEM BORER, *CHILO SUPPRESSALIS* WALKER (LEPIDOPTERA: PYRALIDAE), TO ORGANOPHOSPHORUS INSECTICIDES. Yasuhiko Konno^{*} and Takashi Shishido, Division of Pesticides, National Institute of Agro-Environmental Sciences, Tsukuba-shi, Ibaraki, Japan 305.

The resistant (R) strain of the rice stem borer showed high resistance to organophosphorus (OP) insecticides containing a P-O-aryl bond. The highest resistance was found in heterocyclic esters such as pirimiphos-methyl (resistance ratio=1100). In vivo metabolism of ring- and methoxy-14C-fenitrothion and fenitroxon was studied. The R strain detoxified fenitroxon, which is the actual anti-AChE, far faster than the susceptible strain. Major metabolites were identified as dimethylphosphate, dimethylthiophosphate and 3-methyl-4-nitrophenyl β -D-glucoside. The results indicate that increased detoxication of fenitroxon by cleaving P(O)-O-aryl bond is the principal mechanism of fenitrothion resistance. In vitro degradation of fenitroxon in the R strain was examined. We found that protein binding and esterases were responsible for the fenitroxon degradation. SK-102, which is a novel synergist, was developed in our laboratory. When mixed with pirimiphos-methyl at 1:10 ratio (OP: SK-102), SK-102 reduced resistance from 1100 to 1.1-fold.

#30

EFFECTS OF PESTICIDES ON THE SILKWORM, *BOMBYX MORI* (LEPIDOPTERA: BOMBYCIDAE). S. Kuribayashi, Department of Sericulture, Sericultural Experiment Station, Tsukuba, Ibaraki, 305 Japan.

Pesticides contaminate mulberry leaves and lower their quality occasionally. Silkworms fed with such mulberry leaves experience damage due to poisoning or an associated decrease in food value. The level of contamination of the mulberry leaves producing larval death was 0.02-220 ppm/foliage weight (0.021-1,600 µg per g of larval body weight). The silkworms showed acute symptoms such as twisting with pain, vomiting, sideways rolling and turning or chronic symptoms including inactivity and prostration depending on the kind or quantity of pesticides. Some grew almost normally during the larval period, but died in cocooning frames due to lack of cocooning ability, while others carried out cocooning but died inside the cocoons. Even at sublethal doses, effects such as delayed and uneven growth, abnormal molting, weak body, diseases caused by microorganisms, light and small or uneven cocoons, shortened and uneven thickness of cocoon filament, poor reliability of cocoons, reduced number of eggs, production of abnormal eggs (non-fertilized, embryo death at the initial stage or at the stages immediately before or after hatching) were observed. The period required to reach the permissible level of residue on mulberry leaves after spraying ranged from 3 to 150 days. On the basis of the data, residual toxicity standards for the use of pesticides in a sericulture area were set up.

#31

COMPARISON OF TOXICOLOGICAL TESTING METHODS AND ACARICIDAL RESISTANCE IN FIELD POPULATIONS OF TWO-SPOTTED SPIDER MITE (ACARINA: TETRANYCHIDAE) IN KOREA. S.C. Lee*, S.S. Kim and D.I. Kim, College of Agriculture, Chonnam National University, Kwangju 500, S. Korea.

Three toxicological testing methods for detecting acaricidal resistance in the two-spotted spider mite (*Tetranychus urticae* Koch) were evaluated. The slide dip technique (CV=8.7%) was more precise and rapid than the leaf dip technique (CV=12.2%). Although topical application bioassay with a micro-capillary droplet (CV=8.1%) showed high precision, it was time consuming and difficult to manipulate the micro-capillary droplet. In a comparison of the resistant field populations with a susceptible population, based on LC₅₀ values by slide dip bioassay, populations collected from the Kimhae, Suweon, Naju and Chungju orchards in Korea were 38.8, 24.0, 19.1, and 17.9 times, respectively, as resistant as the susceptible to benzomate. Dicofol resistance levels of Naju, Suweon, Chungju and Kimhae populations were 83.4, 70.2, 57.9 and 48.9 times, respectively. The Kimhae, Suweon, Naju and Chungju populations showed 21.6-, 15.8-, 15.3-, and 10.1-fold resistance levels, respectively, to cyhexatin.

#32

SYNERGISM OF PERMETHRIN AND FENVALERATE IN FOURTH INSTAR LARVAE OF ONTARIO STRAINS OF COLORADO POTATO BEETLE (COLEOPTERA: CHRYSOMELIDAE), BY PIPERONYL BUTOXIDE. A. Mahdavi*, and K.R. Solomon, Department of Environmental Biology, University of Guelph, Guelph, Ontario, Canada N1G 2W1.

The Colorado potato beetle (CPB), *Leptinotarsa decemlineata* (Say), is a major pest of potato, tomato and eggplant in North America, Europe and many other places in the world. As a result of heavy reliance on the use of organic insecticides for control, this pest has been selected for resistance to nearly all groups of insecticides used.

Laboratory studies demonstrated the synergistic effect of piperonyl butoxide (PB) on the toxicity of permethrin (Per) and fenvalerate (Fen) to freshly molted 4th instar larvae of Ontario strains of CPB. 2.5-10 µg PB were used 2 h before application of insecticide at which time PB has its highest effect. PB synergised both Per and Fen against the freshly molted 4th instar larvae of London, Guelph and Parry Sound strains of CPB. In the London strain synergistic ratios (SRs) for Per and Fen were 2.78 and 11.05, respectively. In the Guelph strain SRs for Per and Fen were 13.48 and 35.4, respectively. In the Parry Sound strain SRs for Per and Fen were 8.66 and 36.53, respectively. The results show that this pest has already been selected for resistance to pyrethroids in field situations in Ontario. The significance of the mechanisms of resistance of this pest to pyrethroids will be discussed.

#33

BASE LINE SUSCEPTIBILITY OF *CHRYSONOMYIA MEGACEPHALA* TO FIVE INSECTICIDES (DIPTERA: CALLIPHORIDAE). M. Mihara* and H. Kurahashi, Department of Medical Entomology, National Institute of Health, 2-10-35, Kamiyosaki, Shinagawa-ku, Tokyo 141, Japan.

Chrysomya megacephala (Fabricius) is a very common fly of medical importance in transmitting various pathogens and eggs of intestinal parasites in SE Asia. A synanthropic form of this species is widely distributed in Oriental and Australasian Regions and was accidentally introduced into Afrotropical and Neotropical Regions in the 1970s. Recently, this form seems to be established in the Yumenoshima dumping ground in Tokyo Bay where insecticides have been sprayed for house fly control. Three feral forms are found only in native forests in New Guinea, Australia and the South Pacific islands. Susceptibilities to five insecticides, fenitrothion, diazinon, dichlorvos, permethrin and lindane, were assessed on two of these feral forms and five colonies of the widely distributed synanthropic form originated from Yumenoshima, Hong Kong, Manado, Jakarta and Madang. All colonies were generally susceptible to the insecticides tested, while small but clear differences were observed between synanthropic and feral forms. The Yumenoshima colony was more tolerant to the five insecticides than the other colonies.

#34

EFFECT OF PESTICIDES ON AGRICULTURAL WORKERS. I.K. Nazer*, M.T. Al-Wali, J.A. Al-Khatib and S.A. Khoury, Faculty of Agriculture and Faculty of Medicine, University of Jordan, Amman, Jordan.

The effect of pesticides on the whole blood cholinesterase (ChE) was evaluated in the field. The study involved 18 agricultural workers at the University of Jordan farm in the central Jordan Valley during the agriculture season 1984-1985, and an equal number of non-agricultural workers at a nearby vocational school. The study started in the last week of November 1984, and continued until the end of June 1985. Methods adopted followed the World Health Organization procedure using a "spectrophotometric kit for measuring ChE activity and safe use" unit. A finger prick blood sample was taken from each participant, and the ChE activity determined for each participant using a Lovibond 2000 comparator. The average ChE activity in the blood of agricultural workers ranged from 55.00-65.50%, whereas the enzyme activity in non-agricultural workers ranged from 81.94-91.28%. The enzyme activity in the latter was significantly higher ($P<0.01$) than that in the agriculture workers.

#35

EFFECT OF SUBLETHAL CONCENTRATIONS OF INSECTICIDES ON THE NUMBER OF MATURE EGGS IN THE OVARY OF VIRGIN FEMALE DIAMONDBACK MOTH. Hisashi NEMOTO, Saitama Horticultural Experiment Station, Rokumabnu, Kuki-shi, Saitama 346, JAPAN.

Diamondback moth (DBM) became abundant after applications of methomyl in the cauliflower field but not in the untreated one. It was suggested that the application of methomyl might cause a resurgence of the moth population through the stimulation of the reproductive potential and differential mortality between predators and prey. The adult females derived from the methomyl treated pupae laid more eggs, 17, 8, 12 and 10% increase for 10, 50, 100 and 500 ppm methomyl, respectively and the number of fertilized eggs per female increased 1.3 times at 10 ppm and 1.15 times at 500 ppm as compared with the untreated check. Seventeen insecticides which were used cruciferous plants were applied to the pupae and assessed for chemical stimulation of ovarian development of adult DBM 24 hrs after emergence. The result was that applications of sublethal concentrations of each of the 6 insecticides, phenthoate (100 ppm), cyanophos (10 ppm), diazinon (10 ppm), carbaryl (10 ppm), dichlorvos (10 ppm) and acephate (1 ppm) to pupae of the DBM increased in the number of mature eggs in the virgin female ovary ($X_{1.2-1.3}$).

#36

THE SUBLETHAL EFFECT OF SOME INSECTICIDES ON THE FECUNDITY OF THE TWO-SPOTTED SPIDER MITE. ALY H. RASMY and S. A. ELSAWY, Plant Protection Dept., National Research Centre, Dokki, Cairo, Egypt.

The influence of three insecticides representing the major insecticide classes, synthetic pyrethroids (fenprothrin), organophosphates (pyridaphenthion) and organo-chlorines (Mitran) on the fecundity of *Tetranychus urticae* Koch was studied in the laboratory. When newly matured females were exposed to sublethal residues of these substances, the oviposition period was significantly shortened and the number of eggs laid per female was dramatically reduced. Moreover, the offspring of these exposed females elicited an inhibitory reduction in its fecundity. Females resulted from larvae exposed to the sublethal residues exhibited a more pronounced reduction in egg reproduction.

#37

DEPLETION INDUCED BY PENFLURON IN THE CUTICULAR PROTEIN-CHITIN CONTENT OF *DYSDERCUS CINGULATUS* (F.) AND *ACHOEA JANATA* (L.). C. Reena and Kumuda Sukumar, Entomology Division, Regional Research Laboratory, Hyderabad 500 007, A.P., India.

A benzoylphenyl urea compound, penfluron, was administered topically to the immature stages of *D. cingulatus* and *A. janata*. It was observed that there was a marked depletion in the major compounds viz. protein-chitin content of the cuticle. Qualitative analysis of the integumentary proteins by PAGE were made in the normal and treated juvenile stages of the test insects. Significant changes were observed in the pattern of distribution of cuticular proteins in *A. janata*. In the case of *D. cingulatus* the changes were less apparent.

#38

RELATIONSHIP BETWEEN TIME, DOSE AND SIZE FACTORS OF INSECTS KILLED BY INSECTICIDE APPLICATION. K. Sato, Laboratory of Applied Entomology, Faculty of Agriculture, Tokyo University of Agriculture and Technology, Fuchu, Tokyo 183, Japan

When a certain dose of an insecticide was applied topically to a lepidopterous larva, an insecticidal action soon killed the larva. The products of $(W - W_0)$ and $(T - T_0)$, index of toxic effect, K , resulted in an approximately constant value as given in the equation:

$$(W - W_0)(T - T_0) = K \quad \text{----- (1)}$$

where W is the applied dose of insecticide, W_0 is the minimum insecticidal dose causing larval death, T is the lethal time (time between insecticide application and larval death) and T_0 is the minimum lethal time for a larva.

The value of K for an insecticide increased in parallel with the development of larvae. So, an equation on the relation between K and the larval weight (M) obtained as:

$$K = aM + B \quad \text{----- (2)}$$

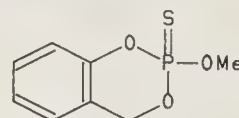
where a and B are determined by the combination of an insecticide and a larva. The smaller the value of a is, the greater is the toxicity to an insect.

The value of K would seem to express the toxicity of an insecticide more dynamically than the LD-50 value, because "K" describes the product of dose factor and time factor on larvae of the same developmental stage (same size), while LD-50 describes only the dose factor over a brief period of time (e.g. 24 hr) after insecticide application to insects.

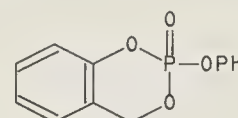
#39

SYNERGIC EFFECT OF SALIGENIN CYCLIC PHOSPHATE WITH FENITROTHION AGAINST ORGANOPHOSPHATE-RESISTANT HOUSEFLY. T. Shiotsuki* and M. Eto, Department of Agricultural Chemistry, Kyushu University, Fukuoka 812, Japan.

Salithion, one of saligenin cyclic phosphates, is known as an effective insecticide against organophosphate-resistant insects. The synergic effect of K-2, an analog of salithion, with fenitrothion has recently been found. The synergism was concluded to be due to the inhibition of glutathione (GSH)-dependent degradation of fenitrothion. It was also observed that some saligenin cyclic phosphates including K-2 and salithion were transformed into active inhibitors for GSH S-transferase in the presence of GSH.



salithion



K-2

#40

MECHANISMS OF PARATHION RESISTANCE IN HOUSEFLIES.

T. Shono* and J.G. Scott, Department of Medical Entomology, National Institute of Health, Shinagawa-ku, Tokyo, 141 Japan, and Department of Entomology, Cornell University, Ithaca, New York 14853, U.S.A.

A strain of housefly extremely resistant (EPR) to parathion was obtained after laboratory selection by ethylfenitrothion (20 generations) and parathion (4 generations) from Third Yumenoshima (3rd-Y), a strain which is resistant to fenitrothion and malathion, but not parathion. LD50 values to parathion in EPR, 3rd-Y and susceptible (S+) strains are >100, 0.60 and 0.022 µg / female fly, respectively. Mechanisms of parathion resistance in EPR houseflies were studied *in vitro* using radiolabeled parathion and paraoxon. The monooxygenase and GSH-transferase of the resistant EPR flies had 2.3 and 3.0 times, respectively, as great activities as those of susceptible S+ flies. These mechanisms in addition to insensitive AChE account for the high levels of resistance to parathion in this strain.

#41

STUDY ON PHYSICO-CHEMICAL BEHAVIOUR OF PESTICIDES BY OBSERVATION OF INSECTS UNDER DOSING OF SUCH PESTICIDES. Makiko Sugiyama* and Ryuitiro Sugisita, Conservation Laboratory, Faculty of Fine Arts, Tokyo National University of Fine Arts and Music, Ueno Koen, Taito-ku, Tokyo, 110 Japan.

Although the good efficiency of DDVP, dimethyldichlorovinylphosphate, as a pesticide utilized in museums and galleries is now well recognized, its physico-chemical behaviour in practice, e.g. diffusion in a storage case, are not exactly clarified. We investigated such behaviour using the method of Masana Suwanai, by observing the action of small red bean (azuki) weevils, *Callosobruchus chinensis*. They were put in rubber-stoppered glass containers with DDVP and the effects of changing the sizes or the shapes of containers, the amount and the location of the pesticide were observed.

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PREVALENT LIMNOENTOMOFAUNA OF VOJVODINA (YU) AND CONSEQUENCE OF LARVICIDES APPLIED FOR MOSQUITO CONTROL. M. Zgomba*, D. Petrić and Ž. Srdić, Institute For Plant Protection, University of Novi Sad, Yugoslavia.

Prevalent limnoentomofauna of stagnant water were represented by the following orders: Collembola, Ephemeroptera, Odonata, Heteroptera, Coleoptera, Plecoptera and Diptera. Larval abundance of orders was regularly recorded in the period March-October for two years. Anti-larval mosquito control corresponded to the same period. Temephos, diflubenzuron and *Bacillus thuringiensis* serotype H-14 (B.t.t.) were highly effective in mosquito control but also have some toxicity on non-target organisms. Compounds based on temephos caused mortality of aquatic entomofauna investigated. Some, but not sufficient, selectivity was shown by diflubenzuron which affected the insects in molting phase only. The biological product based on B.t.t. was highly selective to all tested insects except for aquatic Diptera larvae.

PYRETHROIDS: THE KEY TO SUCCESSFUL DEVELOPMENTS.

Toshio Narahashi, Dept. of Pharmacology, Northwestern University Medical School, Chicago, IL. 60611, USA.

Based on the current knowledge of the mechanism of action at the cellular and molecular levels, we have analyzed factors that made pyrethroids successful insecticides. The primary target site of pyrethroids of both type I and type II is the sodium channel that is responsible for generation of action potentials. When intoxicated with pyrethroids, the sodium channel, which is normally open for a short period of time, remains open for an unusually long period time causing a prolonged sodium current to flow. This in turn keeps the membrane depolarized leading to repetitive discharges in various regions of the nervous system. These changes in sodium channel gating kinetics account for various symptoms of poisoning in animals and insects. Whereas pyrethroids act on both mammalian and invertebrate sodium channels in a qualitatively similar manner, the high negative temperature dependence of pyrethroid action as well as the detoxication factor makes it more potent on insects than on mammals. Certain types of pyrethroids are also known to affect other potential target sites including GABA receptor channel complex, acetylcholine-activated ion channels, and calcium channels. The roles of these sites in pyrethroid toxicity will also be discussed.

BOTANICAL INSECTICIDES AS PROTOTYPES: ISOBUTYLAMIDES, PICROTOXININ AND RYANODINE.

John E. Casida, Dept. of Entomology, Univ. of California, Berkeley, CA 94720 U.S.A.

Three botanicals (piperide and related isobutylamides, picrotoxinin and ryanodine) are prototypes for new insecticides. Many methods are available for preparation of bioactive isobutylamides but total synthesis of ryanodine has not achieved. The neurotoxic mechanism of insecticidal isobutylamides appears to differ from that of other insecticides. Their high potency and effectiveness on pyrethroid-resistant insects are encouraging. Picrotoxinin inhibits the γ -aminobutyric acid (GABA)-receptor. Bicycloorthocarboxylates and ploychlorocycloalkanes, although structurally dissimilar, also block GABA receptors by acting at the same or a closely-coupled site and are much more potent insecticides than picrotoxinin. Toxicity of ryanodine is attributable to uncoupling the electrical signal of the transverse tubule from the calcium release mechanism of the sarcoplasmic reticulum. It has the desired potency on lepidopterous larvae and progress is being made in simplifying the active structures and improving their selective toxicity. Further studies on these botanicals may lead to compounds for improved pest control.

CHARACTERISTICS OF PICROTOXININ RECEPTORS.

Fumio Matsumura, Dept. of Environmental Toxicology and Toxics Substances Program, Univ. of California, Davis, CA 95616, U.S.A.

Picrotoxinin is an active principle of the naturally occurring seed poisons "picrotoxin." Picrotoxinin and its analogs affect the GABA controlled chloride channel, and thereby antagonize the inhibitory action of this inhibitory transmitter in the nervous system. Ligand binding studies using [^{3} H]-dihydropicrotoxinin have shown that there is a specific high affinity receptor which affects the operation of the chloride channel. Cycloidiene-insecticides, gamma-BHC and bicyclophosphates interact specifically with this site. At a first glance, the molecular requirements for "fitting" to the receptor does not appear to be rigid. On the other hand, as shown in the case of the BHC isomers, even the slightest change could drastically alter the affinity of the ligand to the receptor. There appears to be four distinct sites within the receptor. One hydrophobic site which interacts with the "bulky" noncharged end of the chemicals, two sites showing high affinities for the electronegative centers of the ligands, and a site, situated at the opposite end to the "hydrophobic" site, showing an affinity toward the moiety rich with π electrons.

DISCOVERY OF NOVEL SECOND GENERATION AVERMECTIN INSECTICIDES AND ACARICIDES. R.A. Dybas, Merck & Co., Inc., Agricultural Research, Hillsborough Rd., Three Bridges, NJ 08887, USA.

The avermectin family of natural products, produced by fermentation of the soil microorganism *Streptomyces avermitilis*, was discovered in the mid-1970's. These macrocyclic lactones have a unique mechanism of action and appear to block neuromuscular transmission in arthropods by stimulating GABA (γ -aminobutyric acid)-mediated chloride ion conductance. The major component avermectin B₁ (abamectin) displayed the best activity against arthropods and is currently under development worldwide for control of a number of phytophagous mites and insects, both susceptible and resistant to available products. Abamectin shows good safety margins to beneficials and is compatible with IPM practices. Recently, novel second generation avermectins with improved activity against lepidopteran larvae and increased stability on plant foliage were discovered through chemical modification of the natural product, avermectin B₁. It was found that a series of 4"-substituted amino-4"-deoxyavermectin B₁ derivatives, with low mammalian toxicity, were highly effective against a broad spectrum of Lepidoptera. 4"-Epimethylamino-4"-deoxyavermectin B₁ (EMA) was most active with over 1,000 times greater potency against armyworm species compared to abamectin. Modification of the reactive avermectin penta-diene chromophore led to novel compounds with improved stability and persistence on foliage.

EXCITATORY AMINO ACID RELATED COMPOUNDS: ACROMELIC ACID AND OTHER PHYTOTOXINS.

H. Shinozaki, Tokyo Metropolitan Inst. Med. Sci., Honkomagome, Bunkyo-ku, Tokyo 113, Japan.

Pharmacological actions of novel amino acids of natural origin, acromelic acid and stizolobic acid, are presented in order to encourage the utilization of these new and potentially valuable compounds. Acromelic acid is one of the most potent kainoids, and causes a marked depolarization in invertebrates and vertebrates. At the crayfish NMJ, the potency of acromelic acid was about 100 times as potent as that of kainic acid. Ionophoretic application of acromelate produces a depolarization at the crayfish NMJ, in contrast to other kainoids which do not produce such a large depolarization even when large amounts are ionophoretically applied at this junction.

Stizolobic acid reduces responses to quisqualate in a competitive manner at the crayfish NMJ without affecting the GABA and kainoid responses. The blocking action on the quisqualate response is not use-dependent. However, stizolobic acid causes a marked depolarization in the newborn rat spinal cord ventral roots and the adult rat cortical neurones. The depolarizing action is not affected by Mg ions or APV, suggesting that stizolobic acid bind to the receptor other than NMDA-preferred receptors in the rat.

THE ARGIOTOXINS - NON-COMPETITIVE ANTAGONISTS OF INSECT GLUTAMATE RECEPTORS.

P.N.R. Usherwood, Department of Zoology, University of Nottingham, University Park, Nottingham NG7 2RD, U.K.

Two families of toxins which non-competitively antagonize glutamate receptors at insect excitatory nerve-muscle junctions have been isolated from the venoms of araneid spiders. Both families have a polyamine linked to one or two amino acids. They also possess an aromatic moiety, either hydroxyphenol or hydroxyindol.

These argiotoxins cause paralysis when they are injected into locusts and into houseflies. They also postsynaptically depress transmission at glutamatergic synapses on locust and housefly muscle. The onset and reversibility of the antagonism caused by these toxins is both time and toxin concentration dependent.

Single channel studies confirm that argiotoxin₅₃₆ blocks the open channel gated by this glutamate receptor at toxin concentrations as low as 10^{-13} M.

CHEMICAL AND BIOORGANIC STUDIES OF THE PHILANTHOTOXINS.

Koji Nakanishi, Department of Chemistry, Columbia University, New York, N.Y. 10027, U.S.A.

Philanthotoxins, antagonists of the glutamate and acetylcholine receptors, are toxins isolated from the glands of the digger wasp *Philanthus*. We have isolated, characterized and synthesized the major toxin, philanthotoxin-433, which is composed of butyric acid, tyrosine, and spermine-like polyamine residues. We have synthesized several analogs and derivatives and also are attempting to attach the philanthoxins to affinity columns. These aspects will be discussed.

PHILANTHOTOXINS AS INHIBITORS OF INSECT AND VERTEBRATE GLUTAMATE AND ACETYLCHOLINE RECEPTORS.

Mohyee E. Eldefrawi and Amira T. Eldefrawi, Department of Pharmacology, University of Maryland, School of Medicine, Baltimore, Maryland 21201, U.S.A.

The synthesized philanthotoxin (PTX), identical to the natural product isolated from the venom of the digger wasp *Philanthus triangulum*, paralyzes honey bees. It is a potent antagonist of the quisqualate-sensitive glutamate receptor of locust leg muscles. PTX and analogs also act on the N-methyl-D-aspartate type glutamate receptor of mammalian brain. In addition, PTX inhibits nicotinic acetylcholine receptor. PTX does not inhibit binding of ACh or glutamate to their receptors, but binds to an allosteric site located in or near the receptor's ion channel, a site that is more accessible to PTX when the channel is open (i.e. the receptor is activated). This is detected by their inhibition of binding of radiolabeled ligands that bind to these channel sites and/or by receptor-activated tracer ion flux. It is suggested that binding of PTX inhibits receptor function by acting as an open channel blocker of quisqualate- and N-methyl-D-aspartate types of glutamate receptors as well as nicotinic receptors in insects and mammals. (supported in part by NIH grant No. ES 02594).

EFFECTS OF AZADIRACTIN OF EGG PRODUCTION AND FLIGHT PERFORMANCE OF THE BLOW FLY *PHORMIA TERRAE* NOVAE. H. Wilps, Institut für Biologie I, Albertstr. 21 a, D-7800 Freiburg, West-Germany.

Crude extracts of neem seed kernels containing azadirachtin as well as highly purified azadirachtin influence the hormonal system of various insects, especially the hormones which are responsible for the regulation of moulting, fecundity and flight activity. In the larvae of *Calliphora vicina* the ecdyson release by the ring gland is inhibited and the ecdysteroid mobilising monooxygenase system is affected (Koolman, 1987). Experiments done here on adult blow flies show a dosage dependent reduction of egg laying and a decrease of flight performance. After an injection of 0.3 µg azadirachtin/fly at day 3 after emergence flies lose their flight ability during their whole life span. Preliminary results indicate that the glycogen metabolism and its regulating factors released by corpora cardiaca are negatively influenced. In relation to the reproduction rate the ovarian weight and the ecdysteroid content of azadirachtin treated females are reduced.

LE POINT SUR LA LUTTE BIOLOGIQUE AVEC *BACILLUS SPHAERICUS*. N. Monteny*, S. Karch et C. Tonéatti, ORSTOM, Entomol. médicale, 70 Route d'Aulnay, 93140 Bondy, France.

LARVES CIBLES : La cible de *Bacillus sphaericus* est constituée essentiellement par les moustiques du genre *Culex*, selon l'espèce, nuisance ou vecteur de maladie. Plusieurs études récentes ont fourni des informations concernant les processus entraînant la mort : intensité et cinétique d'ingestion des particules bactériennes, transformations physiologiques dans la larve, germination de la bactérie dans le tube digestif conduisant à un recyclage possible dans le biotope.

FAUNE NON CIBLE : L'étude de l'efficacité du traitement de milieux naturels tient compte des compétitions interspécifiques de la faune non cible. Ces organismes peuvent intervenir dans le recyclage de la bactérie en provoquant sa dispersion, son amplification ou sa dégradation en fonction des cycles saisonniers.

LA BACTERIE DANS LE BIOTOPE : En plus de la sédimentation qui lui fait quitter la zone de nutrition des larves, la bactérie est soumise à une inactivation par les conditions abiotiques. Plusieurs processus sont à l'étude.

LA POSITION ECONOMIQUE FACE AUX INSECTICIDES CHIMIQUES : Les avantages et dangers du recyclage naturel et de la spécificité de *B. sphaericus* seront discutés.

STUDIES ON CLOFENTEZINE MODE OF ACTION: PHENOMENOLOGY OF POISONING, ELECTROPHYSIOLOGY, ELECTRONMICROSCOPY AND ENZYME ACTIVITY. Harald C. von Keyserlingk, Schering AG, Agrochemical Research, P.O. Box 650311, D 1000 Berlin 65, Germany.

The new mite ovicide, clofentezine, 3,6-bis(2-chlorophenyl)-1,2,4,5-tetrazine, is inactive against insects *in vivo* and it does not affect electrical signalling between cells in arthropods or the dynamics of muscle contraction in insects. The disruptive effect of clofentezine manifests itself only during a narrow time window in the development of several phytophagous mite species. In the clofentezine treated *Tetranychus urticae* egg cell divisions, yolk formation, development of extremities and the eye proceed unaffected. Instead, the development of the larval tracheal system and the egg spiracles is impaired. No air is ever drawn into the treated egg. The embryo never hatches. Its excretory hindgut develops into a prominent feature at a time when the larva has already hatched from the untreated egg. Occasional muscle contractions, visible as movements of the hindgut can be seen up to 15 days after oviposition when from untreated eggs a new generation of adult mites has already developed. Clofentezine treated *Tetranychus urticae* larvae move slowly, feed little and do not grow. Entry into the moult is far delayed and the moult is never completed successfully. With increasing age *Tetranychus urticae* larvae progressively lose their susceptibility to clofentezine.

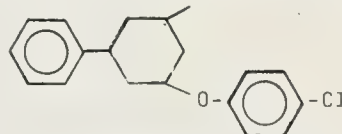
These data will be discussed jointly with the results of an electronmicroscopic study of clofentezine action on *Tetranychus urticae* embryogenesis and a study of clofentezine effects on the activities of several metabolic enzymes.

STRUCTURE-ACTIVITY RELATIONSHIPS IN THE ACARICIDAL ACTIVITY OF SUBSTITUTED DIPHENYL OXADIAZINONES. M. A. Dekeyser, A. Mishra, D. M. Borth, and R. Moore, Uniroyal Chemical Ltd., 120 Huron St., Guelph, Ont. Canada N1H 6N3

The acaricidal activity of a number of 1,3,4-oxadiazin-5-ones has been measured. These data have been analyzed by multiple regression analysis and predictions have been experimentally proven correct. The significant terms in the regression equation are F, R, H_D, and o-MR.

PYRAN DERIVATIVES: A NEW GROUP OF HIGHLY SELECTIVE JUVENIDS, WHICH IS ACTIVE AGAINST *DYSDERCUS INTERMEDIUS* (HETEROPTERA, PYRRHOCORIDAE). C. Künast, W. Himmele, H. Theobald, H.G. Kallenborn. BASF Landw. Versuchsstation und Hauptlabor, D-6703 Limburgerhof; F.B. 15.4 Zoologie, Universität des Saarlandes, D-6600 Saarbrücken.

Pyran derivatives with pronounced juvenoid activity against *Dysdercus intermedius* were discovered in screening tests. A typical compound of this class of substances is MPCD (2-methyl-4-phenyl-6-parachlorophenoxy-5,6-dihydro-pyran):



If during the late larval development tarsal contact takes place with treated sand, then instead of imagines a 6th larval instar develops or, with a low dosage, an intermediate. L6 has as typical larval characteristics shortened wings, a 2-segmented tarsus, reduced genitals. The corpora allata show significant defects. Also the eggs of *D. intermedius* are sensitive to MPCD. With insects of other orders (Lepidoptera, Coleoptera, Diptera) no or only weak juvenoid effects have been observed.

NATURAL INSECTICIDES FROM HIGHER PLANTS - RESULTS OF 5 YEARS SCREENING. W. Pflüger, R. Steffens, U. Wachendorff and G. Zoebelstein*, Bayer AG, Crop Protection Dept., Biological Research, Leverkusen, FRG, D-5090

In our screening laboratory extracts of 530 plant species out of 115 different families were tested for insecticidal or acaricidal activity. Special considerations were given to plant species which were known to be rarely attacked by insects. Five solvents with a wide range of polarity were used to provide crude extracts. Testing was performed with 2 Lepidoptera-, 1 Coleoptera, 1 Homoptera, 1 Diptera and a *Tetranychus* species. Wherever interesting insecticidal activities were observed it was attempted to purify and characterize the active principles. Two examples are harringtonin derived from *Cephalotaxus spec.* - highly active against beetles and caterpillars - and the annonins out of *Annona spec.* - broad spectrum insecticidal compounds. Interesting insecticidal structures are on the way to be characterized from other plant species and will hopefully serve as new leads for insecticides which could be commercially developed.

BIOLOGICALLY ACTIVE MIXED SUCCINIC ACID DI-ESTERS - NEW NONTRADITIONAL TYPE OF POTENTIAL PESTICIDES. J. Kahovcová, Institute of Organic Chemistry and Biochemistry, Czechoslovak Academy of Sciences, Prague, Czechoslovakia.

A series of new mixed diesters of succinic acid with biologically active alcohols were synthesized and tested on various insects and mites. The used alcohols involve juvenile hormone (JH)-, antiJH-like active and steroidal alcohols. Structure-activities relations and possible modes of action are discussed.

QUANTITATIVE GENETIC ANALYSIS OF INSECTICIDE RESISTANCE. B.E. Tabashnik, Department of Entomology, University of Hawaii, Honolulu, 96822, USA.

Tolerance to the pyrethroid insecticide fenvalerate in a diamondback moth, *Plutella xylostella* (L.), population was analyzed by quantitative genetic techniques. Offspring of field-collected individuals were reared in the laboratory as full sib families and tested for tolerance to fenvalerate residues. Mortality varied extensively among families. In most cases, significant among-family heterogeneity in mortality occurred, indicating a significant genetic component. Variation in mortality at 48 hours was essentially continuous and not significantly different from a normal distribution, suggesting that the heritable variation was polygenic. Maximum heritability of fenvalerate tolerance was approximately 0.2. Results from probit analysis suggest that substantial variation in insecticide tolerance is common within insect populations. Quantitative genetic techniques may be useful for estimating the genetic component of intra-population variation in tolerance.

APPLIED ENTOMOLOGY IN THE PRESERVATION OF DOCUMENTS IN BRAZIL. A STATUS REPORT. J.R. Pujol-Luz* and D. Pamplona. Setor de Entomologia - Pró-Documento/Pró-Memória - Rua Pacheco Leão, 2040, Horto, CEP 22460, RIO DE JANEIRO - BRAZIL.

The National Programme for the Preservation of Historical Documents (Pró-Documento), is an action of the Culture ministry, developed by Pró-Memória National Foundation, supporting the preservation of private archives and libraries. Its creation, in 1984, was due first to the importance of these archives in the recuperation of the historical background of the Brazilian civil society for scientific and cultural research, and also to the poor state of preservation of many of these documents that are being destroyed mainly by biological agents, becoming inaccessible to readers or researchers. The laboratories of desinfestation and Quality Control of the Programme (Chemistry, Entomology and Microbiology labs) account for desinfestation and disinfection of books and other documents. This will be done by means of a vacuum fumigation chamber, using 12% ethylene oxide and 88% freon 12. This mixture does not alter the properties of papers and it is an efficient biocide. The entomologists are studying taxonomy, biology and ecology of the main bibliophagous insects and methods to control the efficiency and safety of desinfestation processes. The studies on these insects in Brazil are recent, the literature is rare and foreign and reflect climates other than tropical one.

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A HISTORICAL INSECTICIDE USE PROFILE IN ARIZONA. P.B. Baker*, T.M. Brew, Pesticide Coordinator's Office, University of Arizona, Tucson, Arizona 85721.

The controversy over the growing awareness of the adverse effects of toxic substances and their impact in our modern lifestyle is an issue of worldwide concern. Pesticides are indispensable to current agriculture but have the potential to impair overall quality of air, land, and water supplies. This study was commissioned to identify available pesticide use data and correlate with other information to develop a profile of historical Arizona pesticide/land use. In-state pesticide use data were found to have limitations; additional resources included agricultural statistics, technical bulletins and consultations with individuals experienced in agricultural pest control. Cotton was featured as a heavy recipient of insecticide applications, to demonstrate types of information completed and analyzed. Recommendations for improving pesticide use data in the state were developed.

#97

ANALYSIS OF PERFORMANCE OF TWO EQUIPMENT OF SPRAY (LVC ELEC TRODYN AND ULVA) FOR THE PESTICIDE APPLICATION ON TOMATO PLANTS. J.C. Galli*, M.G. Paranhos, Departament of Entomology and Nematology, Universidade Estadual Paulista-FCAVJ, Jaboticabal, São Paulo, Brazil, CEP 14 870.

This study was carried out with two objectives: a) To study the performance of the electrodynamic sprayer (Electro-dyn, with eletrostatic energy) in different spray procedures over various growth stages of tomato plants using fluorescent dye technique and compare with spinning discs (ULVA-CDA,LCV); b) To determine, for differents Electro-dyn nozzles, some spray parameters such as the type and rate of plant coverage, droplet density and VMD/NMD ratio. In the auxiliary experiment, was obtained that Electro-dyn sprayer produced droplets with high uniformity with VMD/NMD ratio ranging from 1.10 to 1.21 (for Uvitex fluorescent and for pesticide formulation), attending to specification for CDA. All treatments tested (Electro-dyn) at field conditions showed the efficacy on tomato plants. Considering the standard procedures for tractor mounted or knapsack sprayers, the use of Electro-dyn points out the possibility for a drastic reduction of the spray volume, maintaining the efficacy in the control of pests; and about the spinning-disc sprayers (ULVA-CDA) was obtained that the method is practicable only for the median and superior parts of the plant, for two files of the plants.

#98

SYNTHESES OF 2',3'-DIHYDRO-1',4'-BENZODIOXINYL-3,7-DIOXA-BICYCLO[3.3.0]OCTANES AND THEIR INSECTICIDAL ACTIVITY Fumito Ishibashi, Eiji Taniguchi* and Ryuko Takeya Dept. of Agricultural Chemistry, Faculty of Agriculture, Kyushu University, Hakozaki 6-10-1, Higashiku, Fukuoka, Japan 812

The stereoisomers and derivatives of haedoxans, the unique sesquiterpenes of *Phryma leptostachya* L., were synthesized to investigate the structural requirements for their insecticidal activities. Seven diastereomeric ($\pm$)-haedoxan E, eight diastereomeric ($\pm$)-haedoxan A and D, and several derivatives were subjected to the assays on *Musca domestica*. Stereochemical requirements: The compounds having (1S*,2S*,5R*,6S*,2'R*,3'R*) configuration showed the activity at doses below 0.1 μ g/fly with co-administration of piperonyl butoxide. Other diastereomers were inactive even at a level of 10 μ g. (+)-(1S,2S,5R,6S,2'R,3'R)-haedoxan D was highly active, while (-)-(1R,2R,5S,6R,2'S,3'S)-haedoxan D was inactive. The strict stereochemical requirement suggested that the dihydrobenzodioxinyl-dioxabicyclooctanes may act on a specific site of insects. Modification of structure: Acylation and elimination of the hydroxy group of haedoxans, substituents on the phenoxy group at 2-position, replacement of the aryloxy group by other groupings, such as alkoxyl, thio-phenyl and anilino, largely modified the insecticidal activity. Structure-activity relationship will be discussed.

#99

NEEM RESEARCH IN BURKINA FASO. G. Lafleur, Agriculture Canada, Plant Protection Project, B.P. 403, Bobo-Dioulasso, Burkina Faso, West Africa.

Research programs with neem products are underway in Burkina Faso. Foliar sprays of aqueous kernel extracts have been tested in the field against various rice and vegetable pests. Neem has already been successfully used as part of an IPM program for the African rice gall midge, *Orseolia oryzivora* Harris and Gagné. Neem oil, kernel and leaves have also been tested in traditional bins against storage pests. Simple methods for preparation and formulation of neem will be presented, and samples of leaves, fruits, seeds, kernels and neem oil will be displayed.

#100

NEW NONTRADITIONAL PESTICIDES: THEIR BIOLOGICAL PROPERTIES. M.M. Metwally*, S. El-Dessouki and J. Kahovcová, Faculty of Agriculture, Al-Azhar University, Cairo, Egypt and Institute of Organic Chemistry and Biochemistry, Czechoslovak Academy of Sciences, Prague, Czechoslovakia.

Several new succinic acid diesters of biologically active alcohols were checked for the biological activity on non-related insects. The results of the biological tests and mode of action are discussed.

#101

INEFFECTIVE USE OF ULV MALATHION TO CONTROL URBAN *Aedes aegypti* DURING DENGUE EPIDEMICS DUE TO INAPPROPRIATE REGULATIONS. P. Reiter*, G.G. Clark and D.J. Gubler, Dengue Branch, DVBVD, CID, CDC, P.O. Box 4532, San Juan, Puerto Rico, 00936.

Dengue and dengue hemorrhagic fever/shock syndrome are evolving as a major public health problem in the Americas. During an epidemic, control of the vector, *Aedes aegypti*, by Ultra Low Volume (ULV) insecticide is the only emergency measure available. The maximum application rate permitted for ground-applied ULV malathion in the United States (51 ml ha⁻¹) was fixed 25 years ago for the control of nuisance mosquitoes. This rate is used for *Ae. aegypti* control in Puerto Rico and several other tropical countries, although it is only 12% of that recommended by the World Health Organization (438 ml ha⁻¹). In an extensive series of trials in urban San Juan, Puerto Rico, conventional cage bioassays indicated excellent control at 50 ml ha⁻¹, but a surveillance method which directly monitors the impact of the insecticide on the wild *Ae. aegypti* population revealed the treatment to be totally ineffective. We believe the principal reasons for this discrepancy are the behavior of the target species, the density of housing (typical of a tropical city) and a low-grade insecticide tolerance due to cuticular impermeability. Despite the availability of adequate toxicological data, revision of the permitted application rate appears unfeasible. In the event of an emergency, therefore, when public health authorities are obliged to respond by whatever means are available, ULV malathion will continue to be applied at well below the effective application rate. We conclude that precious resources are being wasted due to inadequate field testing and inappropriate regulations.

#102

RADIO-MICROSCOPY AS A METHOD OF BIOLOGICAL QUANTIFICATION OF NEW NONTRADITIONAL PESTICIDE'S MULTI-COMPARTMENT EFFECT. R. Tykva, J. Kahovcová, B. Bennettová, V. Landa, M. Matucha, J. Kolina, J. Křeček, V. Černý, L. Streinz, Z. Wimmer, L. Kohout, M. Romanuk, Institute of Organic Chemistry and Biochemistry, Institute of Entomology, CSAV, Institute of Research, Production and Application of Radioisotopes, Prague, CSSR

A novel non-destructive detection method using both ^{14}C -labelling and the insect's body sections (e.g., *Diptera*) is used for the study of biological action of new mixed succinic acid diesters with biologically active alcohols involving juvenile hormone (JH)-, anti-JH-like active and steroidal alcohols. In comparison with microautoradiography (ARG), the radiomicroscopy offers automatic and quantitative evaluation of local activity expressed directly in the counting rate (cpm) within a relatively short time. Besides, there exists no non-linearity between radioactivity and its record as in ARG. The body sections need no initial preparation before the radioactivity measurements and so they may be used for further processing. According to the evaluated distribution of activity the specific activities of chosen organs are measured. Distribution of radioactivity and the mechanism of biological action are discussed.

#103

ENVIRONMENTAL THRESHOLDS FOR PESTICIDES DERIVED FROM AMBIENT RESIDUES IN SOIL AND SEDIMENT. L. J. Vorgetts, Jr., E. S. Evans, S. R. Evans, J. M. Heller, K. L. Olds, J. F. Suprock, J. B. Vinopal, and T. M. White. U. S. Army Environmental Hygiene Agency (USA-EHA), Aberdeen Proving Ground, Aberdeen, Maryland, 21010-5422 U.S.A.

A difficult problem encountered when making risk assessments of pesticide residues in the environment is ascertaining what concentration represents significant contamination. The U. S. Environmental Protection Agency has not promulgated permissible residual levels, so there are no official guidelines or methods for answering two critical questions: (1) How much is too much or what are appropriate action levels? (2) how clean is clean or what are appropriate clean-up goals?

Unlike most other classes of potential contaminants, pesticides are deliberately introduced into the environment, so residues are an expected consequence of their use. Measurement of this environmental background level, which is a goal of the U.S. Army Pesticide Monitoring Program, is one approach to establishing environmental thresholds for pesticides. More than 5,000 soil and sediment samples have been collected and analyzed since the program began in 1972. Data indicate an ambient pesticide residue level that is below 5.0 mg/kg in soil and 0.1 mg/kg in sediment.

#104

THE IMPACT OF GOOD LABORATORY PRACTICE (GLP) STANDARDS IN THE U.S.A. ON PESTICIDE DEVELOPMENT AND CONTRACT RESEARCH. D.L. Watson*, Watson Consulting and Enterprises, Incorporated, 127 Whittington Course, St. Charles, Illinois 60174, D.J. Harms, Crop Pro-Tech, 33 West Bailey Road, Naperville, Illinois 60540 and R.E. Aschman, Aschman Associates, 2921 Beverly Drive, Des Moines, Iowa 50322.

The enforcement of Good Laboratory Practices (GLP) Standards by the United States Environmental Protection Agency will have a significant effect on Pesticide Development and Regulation. The impact and necessity to comply will be positive for the private research contractor. It will also have a positive impact on companies who are the leaders in all aspects of pesticide development. The viewpoint will be that of private contractors actively engaged in contract research. Standard Operating Procedures (SOP) are basic to the Good Laboratory Practice guidelines and will be covered in detail.

#105

PRODUCTION OF INSECTICIDAL LIGNAN (HAEDOXAN A) BY TISSUE CULTURE OF THE LOPSEED, *PHYMA LEPTOSTACHYA* L. II. PRODUCTION OF HAEDOXAN A AND OTHER LIGNANS IN LIQUID CULTURE. H. Yamada¹, M. Kawamura², A. Masui³, and E. Taniguchi⁴, ¹Kyowa Hakko Kogyo Co., LTD., 100 Tokyo, ²Nouyaku Biotechnology K. K., 103 Tokyo, ³Ageo Research Laboratory, Nippon Kayaku Co., LTD., 362 Saitama, and ⁴Department of Agrochemistry, Kyushu University, 812 Fukuoka, Japan.

In production of available compounds by plant tissue culture, liquid culture is generally superior to agar culture. Since HA contents were very low in callus or root culture, we mainly examined HA production by root formation from shoots in liquid culture.

HA contents in plantlets were 6.6 times higher in shake culture than in agar culture. Roots were more than 30% of plantlets in root formation culture for four weeks, however, HA contents in plantlets were maximum at six weeks. It was observed in addition that a large amount of HA and other lignans was excreted in culture medium. HA contents in the medium were maximum at five weeks. Culture using 5l jar fermentor was examined in order to research possibilities of industrial scale culture. Contents of HA and other lignans in roots, leaves and stems, and the medium were 173 and 1,683 $\mu\text{g/gFW}$, 18.6 and 713 $\mu\text{g/gFW}$, and 0.033 and 3.06 $\mu\text{g/ml}$. Production of HA and other lignans in plantlets was 1.2 times larger than that of original plants.

It was confirmed that crude lignans containing HA extracted from plantlets and the medium had insecticidal activities.

#106

DEVELOPMENT OF INSECTICIDE RESISTANCE IN DIAMONDBACK MOTH (*PLUTELLA XYLOSTELLA* L.; LEPIDOPTERA, PLUTELLIDAE) in Thailand 1965 - 1987

G. Zobebelein, Bayer AG, Crop Protection Dept., Biological Research, Leverkusen, FRG, D-5090

From 1965 strains of *Plutella xylostella* from Thailand were collected at irregular intervals and examined by means of a leaf dip test for resistance to numerous insecticides. The studies revealed a constant increase in the level of resistance to the new compounds that were continually launched. These studies disclosed crossresistance between some organophosphates and in particular between DDT and pyrethroids. According to the findings obtained up to 1985 there was more or less high resistance to organophosphates, carbamates, chlorinated hydrocarbons and pyrethroids. In addition since 1986 resistance to IGR's notably benzoylphenylureas has been discovered.

#107

SURVEILLANCE OF DEVELOPMENT OF INSECTICIDE RESISTANCE IN THE DAMSON HOP APHID (*PHORODON HUMULI* (Schränk); HOMOPTERA, APHIDIDAE) 1965 - 1987. G. Zobebelein, Bayer AG, Crop Protection Dept., Biological Research, Leverkusen, FRG, D-5090. Compounds of the demeton-group have been used successfully by hopfarmers in southern Germany for nearly 15 years to control damson-hop aphid. After farmer complaints in 1965 samples of *Phorodon humuli* have been tested in our lab by a simple leaf dip technique, confirming resistance to the demeton-group. Therefore these compounds were replaced by other organophosphates and new carbamates. The resistance development to some of them has been followed up yearly. By 1977 *Phorodon humuli* showed a more than 100 fold resistance to acephate, dimefox and oxydemeton-methyl and about 25 fold to omethoate, methidathion and methamidophos. Carbamate resistance was below 10 fold. With the introduction of pyrethroids a rotational spraying program has been established since 1979 stabilizing the resistance situation until now.

#108

VARIABILITY OF WATER PH IN SOUTH CAROLINA (USA) AND POTENTIAL IMPACT ON TOXICITY OF PESTICIDES USED IN URBAN PEST CONTROL PROGRAMS. P.A. Zungoli, Department of Entomology, Clemson University, Clemson, South Carolina 29634-0365 USA

Recent studies have reported that variations in water pH can cause a reduction in pesticide toxicity. The toxicological half-life for a chemical can range from a few minutes to several weeks. A study was conducted to determine pH for water sources throughout South Carolina (USA). All major municipal water sources in the state were included. Many water sources measured in the alkaline range above pH 7. Many products used in household, structural, and ornamental pest control are affected when mixed in water that is either highly acidic or basic, resulting in poor control. Data from this study indicates that the addition of pH buffering agents to chemicals at mixing can increase pest control success. However, buffering agents tend to affect water sources differentially and must be determined on an individual basis.

**Insecticide Resistance:
New Diagnostic Tools For Detection And Management**

FIELD MICROPLATE DETECTION OF INSECTICIDE RESISTANCE IN SINGLE INSECTS. W.G. Brogdon, Centers for Disease Control, Atlanta GA, USA.

No Abstract

SOME NEW METHODS FOR REVEALING GENETIC VARIANTS AT SPECIFIC LOCI, AND THEIR POSSIBLE UTILIZATION IN DETECTING INSECTICIDE RESISTANCE. D.G. Heckel, Clemson University, Clemson SC, USA.

No Abstract

DETECTION OF INSECTICIDE RESISTANCE BY IMMUNOLOGICAL ESTIMATION OF CARBOXYLESTERASE ACTIVITY IN *MYZUS PERSICAE* POPULATIONS.. R. ffrench-Constant, Cornell University, Ithaca NY, USA

No Abstract

SIMPLE BIOCHEMICAL DIAGNOSTIC TESTS FOR MONITORING ORGANOPHOSPHATE INSECTICIDE RESISTANCE IN MOSQUITOES. G.P. Georgioliou¹ & N. Pasteur², ¹University of California, Riverside CA, USA; ²CNRS, Montpellier, France.

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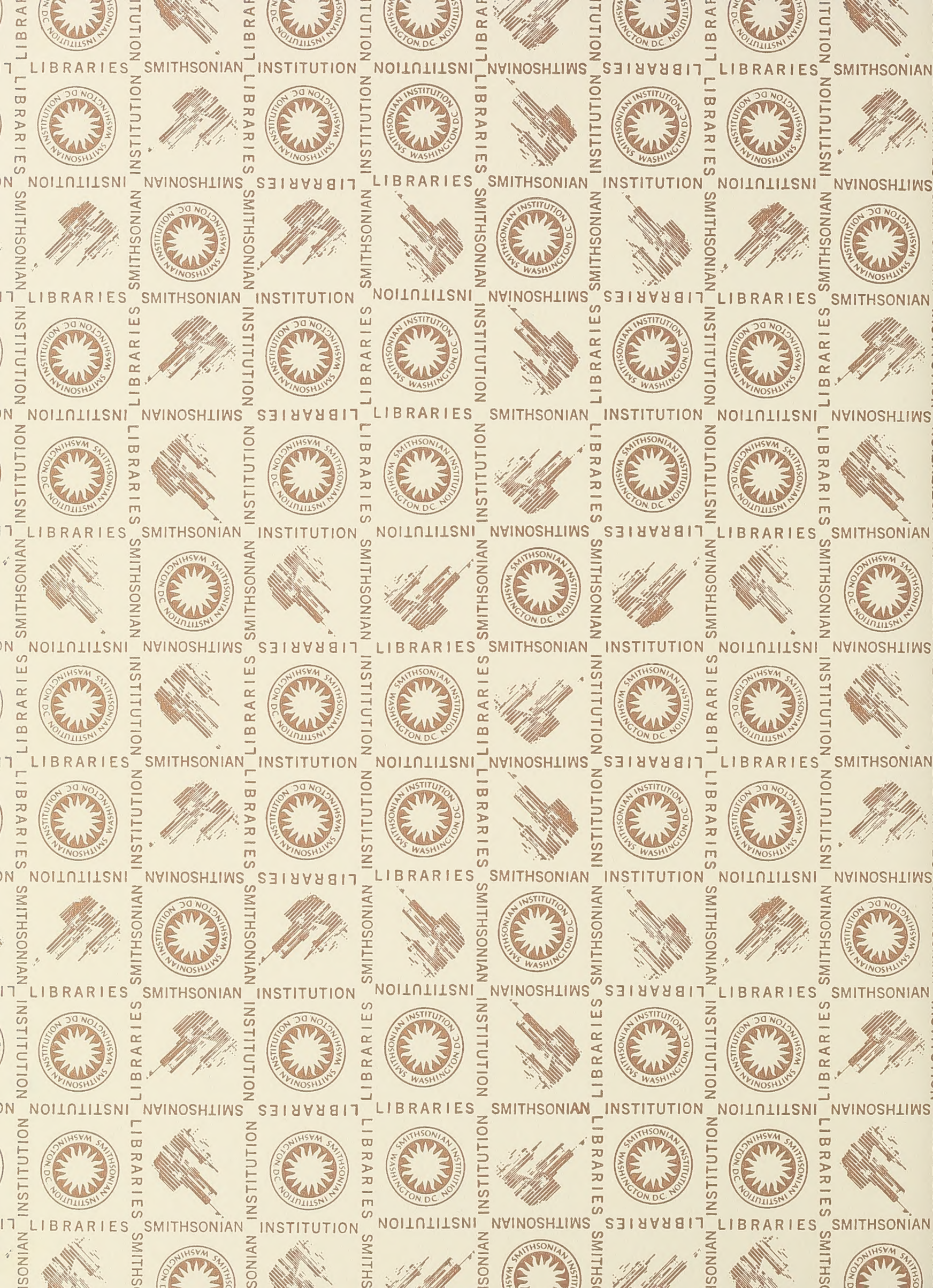
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